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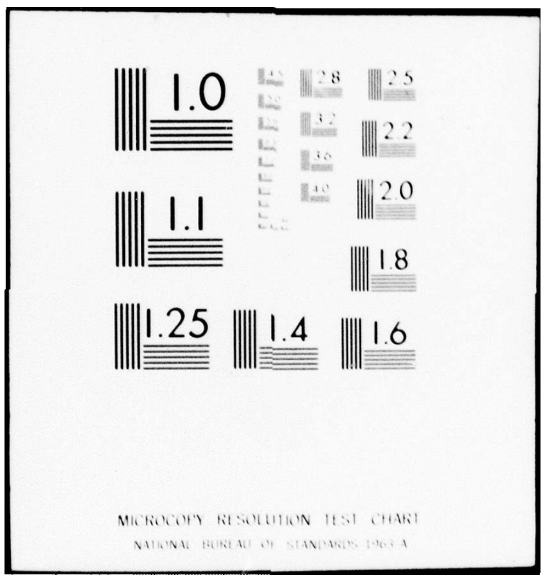
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IPC Design Validation and Flight Testing

Final Report

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16. Abstract

A series of flight tests were conducted to evaluate the collision avoidance system known as Intermittent Positive Control (subsequently re-named Automatic Traffic Advisory and Resolution Service, ATARS). These tests involved both professional test pilots and subject pilots selected from the aviation community. This report includes analysis of the collision avoidance algorithm, pilot visual acquisition performance, and pilot reaction to avoidance instructions.

ABSTRACT

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EXECUTIVE SUMMARY

Background

Flight tests of the Intermittent Positive Control (IPC) system have examined the performance of an automated collision avoidance system in a realistic flying environment. These tests were conducted for the Federal Aviation Administration at the M.I.T. Lincoln Laboratory using an experimental DABS sensor for surveillance and data link, and using IPC computer algorithms provided by the MITRE/METREK Corporation. The tests had two principal objectives: 1) to characterize the performance of the IPC computer algorithms, and 2) to determine the manner in which pilots are able to utilize the services provided by the IPC system. The test program was organized in a manner that permitted design iterations to proceed during testing: Test results were reported to an IPC Engineering Coordination Group and algorithm modifications originating within that group as a result of test findings were returned to Lincoln Laboratory for testing.

This summary serves as a brief statement of test results, conclusions, and recommendations. Detail in support of this summary is contained in the body of the report and in its appendices.

Algorithm Validation

Algorithm validation testing sought to characterize the ability of the IPC algorithm to issue commands which assured safe separation between aircraft.

The behavior of the IPC system was compared to the qualitative descriptions of IPC. These descriptions have been published in the form of standard encounters in which threat development and pilot responses follow prescribed patterns. The principal characteristics of these nominal encounters are that they involve two aircraft with similar speeds, both equipped for and fully responsive to IPC commands, with neither accelerating as the conflict develops. Flight test results indicate that for such nominal encounters IPC consistently detects and resolves the presented collision hazard. The only significant safety problem with regard to nominal encounters was a tendency for some encounters to terminate in a potential hazard in which a return-to-course executed to recover the original heading could have precipitated a second collision hazard worse than the original.

Non-nominal encounters are those which violate one or more of the standard conditions. They may involve aircraft of greatly dissimilar speeds, acceleration during conflict development, one aircraft unequipped, etc. Flight tests indicated that for non-nominal encounters, IPC performance could be very inconsistent. Collision avoidance commands could be late, ineffective, or even detrimental to safety. Particular difficulties were observed in accelerating encounters in which the rapidly changing geometry of the conflict often resulted in the system issuing commands which decreased rather than increased separation. Since pilots are typically not aware of the encounter attributes which produce resolution difficulties (e.g., the other aircraft unequipped, uncommanded, or in a pre-existing maneuver), pilot confidence in the overall system can easily be undermined by flying a non-nominal encounter and observing the resulting IPC-generated commands.

A detailed analysis of the conflict avoidance logic has revealed that there are several basic and interrelated causes for the observed limitations of IPC effectiveness. Among the significant conclusions are the following:

- The IPC logic does not properly analyze aircraft trajectories in a way that considers all factors critical to making correct resolution decisions.
- Excessive or counterproductive turns often result from the lack of uplinking computed turn magnitudes (currently turns are continued as long as the tracked collision parameters exceed detection thresholds).
- The inability to resolve accelerating encounters results principally from the attempt to achieve a lower system alarm rate by deferring action until a time-critical collision hazard is confirmed by tracking.

Some of the performance limitations are due to limitations imposed by the system concept, while others are associated with the specific algorithm implementation. None of the observed major problems is likely to be resolved by modifying a single section of the algorithm or by varying algorithm parameters within the constraints of the existing logic. The algorithm and system concept must be altered in a fundamental manner (see following recommendations).

Subject Pilot Test Results

The PWI service of IPC was favorably received by subject pilots as an aid to VFR flight. Analysis of test data revealed that use of PWI resulted in a marked improvement in the ability of pilots to visually acquire approaching

threats. There appear to be no major logic issues concerning PWI, although a need for augmenting information given to aid pilots in avoiding blunders in the period before visual acquisition is indicated.

It became apparent early in the subject pilot testing that a complete assessment of pilot response to IPC commands required an understanding of how pilots who were uninfluenced by commands resolved conflicts by purely visual means. For this reason a small subset of the pilots was randomly selected to participate in an exercise during which PWI was provided for aiding visual acquisition, but commands were not provided. In these PWI-only tests the pilots were instructed to take evasive actions only when they felt the situation warranted. The most significant findings of these experiments involves the dependence of perceived urgency and threat level upon the visual evaluation capability at a given time. After visual evaluation, pilots typically approached similar general aviation aircraft far closer than any radar-based system could permit without alarm (less than 200 feet vertically and less than 1500 feet horizontally). Such proximity is accepted because as the aircraft approach closer, the pilot is better able to discern any existing components of miss and to choose suitable maneuvers if required. Visually motivated maneuvers were apparently undertaken to place aircraft on non-collision courses and/or to allow maintenance of visual contact. No effort to achieve a predetermined conservative separation was evident.

In contrast with the results observed when an adequate visual evaluation had been achieved, a tendency for early reaction was exhibited by the same pilots in encounters with little or no visual information. Pilots with PWI

indications in visually obstructed sectors tended to maneuver so as to locate the indicated traffic, or, if PWI's persisted without visual acquisition occurring, to execute avoidance maneuvers based upon the PWI information. Thus, it can be inferred that pilots without visual information adequate for their own evaluation of the situation are likely to be most receptive to suggestions or advice on conflict resolution. Conversely, pilots who are permitted to approach within the domain of see-and-avoid will undoubtedly be reluctant to make major concessions to an automated system.

These insights into visual avoidance behavior were reinforced by pilot reactions to the IPC system commands. Positive commands generated after pilots had acquired adequate visual information were often unfavorably received, either because they were viewed as unsafe (e.g., in wrong direction or eliminated visual contact) or were clearly unnecessary. On the other hand, pilots were generally receptive to commands which came prior to visual acquisition.

It was discovered that the frequency of commands is not the decisive factor in determining the extent to which the pilot feels imposed upon by the system. Of real importance are the magnitudes of the required perturbations to the flight path and the peak workload induced by compliance and recovery. Negative commands were radically different from positive commands in this regard - normally they reduced the level of stress in the cockpit and did not require the pilot to modify his desired flight path.

Conclusions

The observed benefits of PWI service and the success of the IPC system in consistently resolving certain types of collision threats indicate that

ground based collision avoidance using the DABS surveillance and data link is conceptually and technically feasible. But in order to achieve an acceptable system design, the effectiveness of the IPC resolution logic must be extended to cover a wider range of encounter situations and the system must be made more compatible with the objectives and practices of its users. Certain conclusions which are suggested by flight test experience run counter to the conventional philosophy of collision avoidance system design. It is concluded, for instance, that

- It is not possible to design a reliable collision avoidance system which applies control only after an imminent collision hazard is confirmed - at such a point the situation is often beyond control.
- Abrupt assumption of control in the final seconds before closest approach is incompatible with the training and temperment of pilots. The later control is activated, the more likely are pilots who have acquired visually to view commands as unnecessary or incorrect. Furthermore, the high maneuver rates and large turn magnitudes, required by such a strategy make commands unacceptably disruptive.
- Avoidance strategies which ignore or override other flight objectives or separation assurance techniques (e.g., ATC or visual avoidance) may interfere with those techniques in a way that considerably reduce the net safety benefits of the system.

Recommendations

Throughout this report many suggestions are presented for improving IPC performance in particular areas. But convergence of the IPC design is unlikely

to be achieved through a mere addition to the existing logic of independent fixes to local problems. Instead, a global strategy for system evaluation must be formulated. The remainder of Part I recommends directions for system evolution which can result in an acceptable and implementable design.

Recommendations Regarding the System Concept

1. Provide more information to pilots prior to the need for urgent or mandatory commands.
   - In the current logic no information concerning the hazards created by maneuvering in particular directions is provided until after a hazardous closure rate has been established. Often this is too late for effective commands. Pilots should be informed whenever maneuvers would precipitate encounters which the system might not be able to resolve.
   - More comprehensive and precise PWI information is needed to allow pilots to make proper decisions prior to visual evaluation. The first step in this direction should be to provide more precise information concerning threat relative altitude.
2. Recognize recovery encounters as a problem and attempt to issue commands which will assure decisive resolution with a single sequence of commands.
   - This strategy would avoid the excessive conflict durations associated with multiple sequences of commands.
   - This strategy would also avoid the tendency of IPC to turn straight and level encounters into maneuvering encounters.

3. Specify the required maneuver magnitudes to the pilot.

- Such specification reduces the required deviation from intended course.
- The resolution of multiple encounters and the ability of the system to resolve a pair encounter without creating a secondary encounter with a third aircraft is facilitated. IPC can then be extended to greater traffic densities than would otherwise be possible.
- Pilots and controllers wish to anticipate the effect commands will have upon navigational objectives and other control objectives. This is impossible to do if maneuver magnitudes are unknown.

d. Turning aircraft past optimum escape headings and back into conflict can be avoided.

4. Resolve more encounters with minor heading changes at earlier lead times.

- Such commands are more acceptable to pilots than large magnitude turns given at the last instant. They are less likely to interfere with visual search.
- Disruption of structured traffic flow is minimized and therefore the ability of IPC to operate in conjunction with the existing ATC system is enhanced.
- Resolution of multiple encounters or resolution of pair encounters without creating a secondary encounter with a third aircraft is facilitated.

5. Utilize additional information to enhance compatibility of IPC control with pilot objectives

   - Utilize the DABS data link to permit the pilot to accept responsibility for visual separation when visual acquisition has occurred. Any system without this capability will very likely produce unacceptable results in attempting to resolve encounters involving VFR aircraft.
   - Consider the use of other information (e.g., flight destination, phase of flight, short-term intent, aircraft type/performance, etc.) in order to enhance control compatibility. This may be required in order to extend IPC into airspace where collision protection is most needed.

<u>Recommendations Regarding the IPC Algorithmic Logic</u>

1. Make conflict detection a function of the complete dynamics of the encounter.
   - Start earlier for more difficult geometries and issue restrictive commands earlier in geometries for which resolution success is maneuver-sensitive.
2. Evaluate command effectiveness before command issuance.
   - The current logic sometimes issues commands which are obviously ineffective due to dynamic considerations. Valuable time may be wasted before additional action is taken.
   - The algorithm's evaluation of the resolution dynamics should be complete enough to recognize obvious difficulties and to

issue initial commands which have high probability of being adequate or at least not complicating subsequent control.

3. Allow the logic to issue "go straight" commands (e.g., maintain heading).
   - This is sometimes the only acceptable horizontal command for slower aircraft in conflict with a faster aircraft. It may also be a required command for the proper resolution of multiple aircraft encounters.
4. Use staged resolution in all appropriate dynamic situations.
   - Most encounters can be resolved by maneuvering only one aircraft. This is how collision hazards are normally averted today in both VFR and IFR flight.
   - Staged resolution offers a potential for a significant reduction in the rate of positive commands in both VFR/VFR and IFR/IFR encounters.
5. Develop a turn rate estimation capability and utilize this estimate in the resolution logic.
   - The current turn rate detection flag is not appropriate for this application and cannot be used in the resolution logic.
   - Currently, resolution proceeds on the assumption that all aircraft are flying straight at the time commands are selected. Modification of the resolution strategy on the basis of detected maneuvers will avoid many problems with the present approach.

6. Utilize three-dimensional resolution tactics whenever appropriate.
   - Three dimensional logic offers a means of cleanly resolving certain climbing/descending encounters which are otherwise difficult to resolve.
7. Provide for explicit consideration of surveillance errors.
   - These errors are neither isotropic nor homogeneous.
   - Fixed algorithm thresholds are therefore inappropriate for achieving safe separation with minimum disruption of normal flight.

1. INTRODUCTION

1.1 Test Objectives

Flight tests of the Intermittent Positive Control (IPC) collision avoidance system were conducted at the M.I.T. Lincoln Laboratory between October 1974 and February 1977. The objectives of the tests were twofold: to validate the IPC algorithm design by determining that it provided acceptable performance, and to evaluate the ability of typical general aviation pilots to utilize the services provided by the system.

The IPC concept subjected to test was developed jointly by FAA/OSEM and the MITRE/METREK Corporation. Reference 1 describes the basic elements of this concept. Computer algorithms were developed first for single DABS sensors (Ref. 2) and later extended to include cooperation among several sensors (Ref. 3). The single-sensor algorithms tested during the IPC flight tests can be viewed as a subset of the multisite algorithms.

Flight testing was carried out in accordance with a Flight Test Plan (Ref. 4) which emphasized the need for both algorithm validation and subject pilot tests.

In an effort to achieve meaningful and comprehensive results, an iterative testing method was adopted. Test procedures and the system design were modified in response to test experience and the modifications subjected to further testing. Test results were reported frequently to the IPC engineering coordination group which included representatives from M.I.T Lincoln Laboratory, FAA/SRDS, FAA/NAFEC, and MITRE/METREK. Algorithm modifi-

cations were normally developed by MITRE/METREK for submission to the group. Interim flight test results, including initial validation experience, were reported in Ref. 5. The present report includes an overview of all testing, an analytic perspective on validation results and an overall assessment of the viability of the IPC concept.

1.2 Organization of the Report

A summary of those features of the IPC concept which are most important for understanding the significance of test results is provided in Section 2. The success of the test program required development of a comprehensive testing capability including hardware elements, software elements, test procedures, and data analysis techniques. Many near miss encounters were required to fully exercise the IPC logic and to test modifications. An overview of the test bed facilities and the scope of the test activities is provided in Section 3. The presentation of flight test data has been divided into two parts: algorithm validation and pilot response analysis. The algorithm validation section (Section 4) discusses the ability of IPC to utilize DABS data to determine aircraft trajectories and the ability of the logic to issue instructions which achieve the system control objectives. The pilot utilization section (Section 5) discusses the ability of pilots to properly utilize IPC services and the acceptability of system performance from the pilot's point of view.

In order to understand the behavior of the IPC system, an analytical technique for the analysis of aircraft relative motion was developed. This technique is described in Appendix A and is freely used in this report to interpret test results. It is recommended that the reader desiring an in-depth understanding of flight test results familiarize himself with this appendix before reading Section 4 and refer back to the appendix as needed to understand the analysis techniques being applied to particular problems. Appendix B contains a compilation of subject pilot responses to post-flight questionnaires. Appendix C consists of a number of examples of flight test encounters which illustrate certain phenomena discussed in the text.

2. DESCRIPTION OF THE TESTED IPC SYSTEM

2.1 The IPC Concept

Most of the IPC flight testing and data analysis was directed toward determining whether or not the system performed as intended. For this reason it is necessary to understand the fundamental features of the IPC concept in order to judge the significance of test results. The IPC concept is best described by giving a description of how the system is intended to be used and how it is intended to perform. The concept documentation references for IPC (Refs. 1, 2, and 6) rely heavily upon scenarios and qualitative descriptions of how the system will be experienced by the pilot. A quantitative formulation of IPC performance goals cannot be derived from this concept documentation in any straightforward manner. But the motivations for significant design features can generally be found. Since several aspects of the design are based upon explicit instructions to the pilot concerning how he should react to the various IPC messages, much of the concept validity is dependent upon the ability and willingness of pilots to fly the system "by the book". A discussion of test results in this area is provided in Section 5. It should be kept in mind that the following description of IPC describes only how the system in intended to perform - actual performance observed in flight tests will be discussed later. For a more detailed description of the IPC concept the reader is referred to the referenced documents.

The IPC system is capable of providing two basic types of service to aircraft which are equipped with altitude reporting (Mode C) DABS transponders

and an IPC display. First, the pilot is assisted by means of a pilot warning instrument or PWI* in the visual acquisition of nearby traffic.

Second, pilots receive IPC commands which specify maneuvers to be undertaken to resolve conflict situations. PWI service and resolution service are normally provided concurrently through a common display. Options for a PWI-only service and for PWI warnings against non-Mode C aircraft are mentioned (Ref. 1, pp. 2-25), but no design for such options has been documented.

2.1.1 PWI

The IPC display (Fig. 2-1) contains a ring of 36 PWI lights. Three lights are located at each of 12 clock positions. The clock position indicates the relative bearing of the traffic. The central light at each clock position is used for traffic that is within $\pm$ 500 feet of own altitude. The upper and lower lights indicate traffic which is above or below the co-altitude band but within 2000 feet of own altitude.

PWI indications are intended to assist the pilot in visually acquiring proximate traffic. They are not intended to provide enough information for selection of avoidance maneuvers and are not to be used for such purposes by pilots (Ref. 6, p. 7). Two types of PWI are possible. The ordinary PWI (OPWI) takes the form of a steady light at the appropriate position. The OPWI indicates traffic which are not of immediate concern (Ref. 1, p. 2-1) and thus the OPWI does not require the immediate attention of the

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*A PWI is sometimes referred to as a proximity warning indicator.

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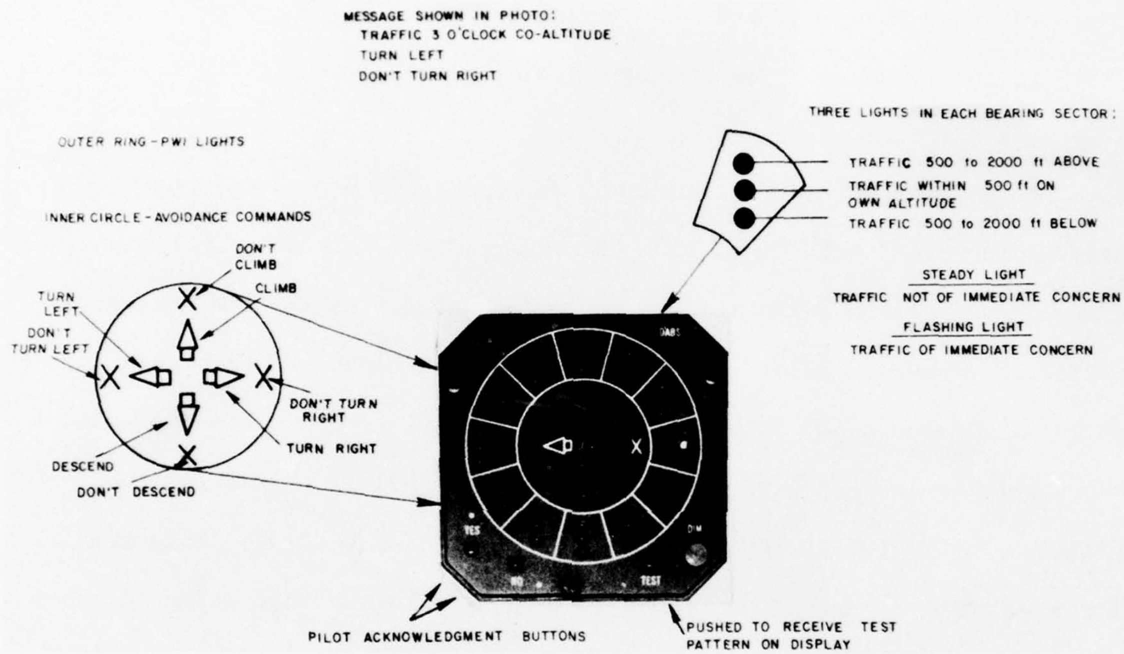

Fig.2-1. IPC display utilized in flight testing.

pilot. For this reason the OPWI need not be accompanied by an audio alert (Ref. 6, p. 6). However, the pilot is expected to check for the presence of an OPWI before initiating any maneuver. If traffic is indicated in the direction of his intended maneuver, the pilot should attempt to acquire it (Ref. 1, p. 2-6). If the pilot fails to acquire the indicated traffic he may maneuver as he sees fit (Ref. 5, p. 7).

The flashing PWI (FPWI) is issued when aircraft are on direct or near collision courses (Ref. 6, p. 8). It requires immediate pilot attention and is accompanied by an audio alarm. The pilot should acquire the indicated traffic as soon as possible. After visual acquisition, the pilot may initiate any evasive maneuver he deems appropriate (Ref. 6, p. 8). It is intended that a reasonable period of time be provided for pilots to resolve the collision hazard before IPC commands appear (Ref. 1, p 2-9). This enables pilots to maneuver according to their own wishes rather than being told how to maneuver by the system. If the pilot chooses not to maneuver, the FPWI will at least prepare him for prompt execution of any commands which appear (Ref. 7, p. 2-3).

2.1.2 Commands

Two types of IPC commands are possible: negative ("don't") commands and positive ("do") commands. Negative commands are displayed by lighting a red "X" at the position corresponding to one of the four possible maneuver directions. They instruct the pilot not to maneuver in the indicated direction.

They are issued when current aircraft trajectories are safe but a maneuver by either pilot would create an immediate collision threat and lead to an immediate positive command (Ref. 1, p 2-9). Positive commands are displayed by lighting a green arrow. They are issued when a conflict has become critical and actions are required immediately to assure safety (Ref. 1, p. 2-8). They are selected to achieve the greatest physical separation between aircraft (Ref. 1, p. 2-8). They are also selected to provide maximum separation even if one of the aircraft fails to respond (Ref. 1, p. 2-24). The command may not be consistent with pilot desires, but the urgency of the collision threat justifies overriding his concerns (Ref. 1, p. 2-8). Even though individual positive commands may inconvenience the pilot, their frequency will be low enough to prevent serious disruption of his total flight objectives (Ref. 1, p. 2-8). In order to achieve a low command rate, commands are delayed as long as possible in order to allow additional time for the situation ro resolve itself without IPC intervention (Ref. 1, p. 2-8).

When a positive command is received the pilot should begin executing it immediately whether he has seen the traffic or not (Ref. 6, p. 12). He should then push the acknowledgement button to indicate that the message has been received. The pilot should maneuver in the indicated direction until the command symbol is extinguished. He should turn with at least 20 degrees of bank and climb or descend with a rate of at least 1000 feet per minute (if possible). Higher rates of maneuver will provide an extra margin of safety (Ref. 6, p. 12-14). Commands are mandatory. IFR pilots must comply with

commands even if it means deviating from their clearance (Ref. 6, p. 18). If a pilot cannot comply fully with a command to maneuver in a certain direction (e.g., if he is VFR and the maneuver would carry him into a cloud), then he should comply to the extent practicable. He is free to maneuver in any maneuver plane in which commands do not exist, but he should not attempt to resolve the hazard by maneuvering in a direction opposite to existing commands (Ref. 6, p. 15). To emphasize that a pilot should not maneuver contrary to a positive command, a red "X" in the position opposite the green arrow is provided whenever a green arrow appears.

2.1.3 ATC Interface

In encounters involving one or more controlled aircraft, the air traffic controller who is responsible for the controlled aircraft is alerted to the possible collision at a tau value of 120 seconds. This controller alert will generally appear before any IPC messages have been sent to the aircraft, although in cases of low closure rate ordinary PWI may have already been issued (Ref. 1, p. 2-12). IPC thresholds for IFR and VFR aircraft differ so that in IFR/VFR encounters the VFR aircraft resolves commands first so that the encounter can be resolved by his maneuver alone. The IFR aircraft rarely receives either positive or negative commands in such cases (Ref. 1, p. 2-25). The controller is notified of all commands issued to or issued because of aircraft under his control. Any commands required for an IFR aircraft equipped only with a Mode-C ATCRBS transponder can be displayed to the

controller and relayed on the voice channel (Ref. 1, p. 2-26). IPC thresholds are such that positive commands are not generated unless violation of ATC standards has already occurred or is virtually certain to occur. It is not the intention of IPC to prevent violation of IFR separation standards (Ref. 1, p. 2-19). No specific provision is made for cancellation of commands by the controller or for other controller interaction with the algorithmic logic. The controller can generally avoid IPC commands between two controlled aircraft by simply maintaining normal ATC separation standards (Ref. 1, p. 2-19).

2.2 The IPC Test Bed Algorithm

The presentation of test results requires frequent reference to particular sections of the IPC computer algorithm. Although changes to the algorithm were made during testing (see Section 3.3), the basic structure of the algorithm was not significantly altered. The data inputs to the algorithm are the DABS position reports and DABS downlink messages. The basic structure of the logic is exhibited in Table 2.1 in the order in which logic modules are normally entered in processing a single encounter on a given scan.

All Mode-C equipped aircraft are tracked and subjected to coarse screening. Aircraft pairs which are identified by coarse screening are subjected to detection. The detection logic determines the types of IPC messages (controller alerts, OPWI, FPWI, or commands) which are justified by the current trajectories. If commands are requested, a record of IPC activity is begun and carried from scan to scan. The resolution logic generates and updates IPC commands. The actions of the resolution logic depend upon previous algorithm states as well

as the output of the detection logic. The resolution processing is done in a strictly pairwise manner - each pair of aircraft is fully processed before the next pair is considered.

TABLE 2-1

MAJOR SECTIONS OF IPC TEST BED ALGORITHM

ALGORITHM SECTION	FUNCTION
Tracking	Estimate current aircraft positions and velocities.
Coarse Screening	Identify all pairs of aircraft which may pose potential hazard to each other.
Threshold Selection	Select tau and miss distance thresholds to be used for a particular pair of aircraft.
Detection Filter	Determine whether PWI or commands should be sent to each aircraft. Determine whether OPWI or FPWI is required. Determine whether controller alert is to be sent.
Resolution	
2/3 Logic*	Decide if command request is persistent (2 out of 3 scans).
Command Selection Logic	Determine plane and directions of commands.
Positive/Negative Transition Logic	Transition from positive to negative commands and vice-versa.
Compliance Logic	Determine if VFR aircraft is in compliance and alter strategy if not.
Acknowledgement Logic	Determine if aircraft have acknowledged commands and issue additional commands if not.

*Although it is structurally part of the resolution logic, the 2/3 logic is functionally an extension of the detection filtering criteria.

3. FLIGHT TEST OVERVIEW

The IPC flight test plan (Ref. 4) contains descriptions of the basic test facilities and test methodology. Section 3.1 and 3.2 which follow present a brief review and update of those descriptions. Section 3.3 presents a summary of flight test activities and documentation.

3.1 Test Facilities

The IPC flight tests were conducted at the Discrete Address Beacon System Experimental Facility (DABSEF) operated by M.I.T. Lincoln Laboratory, Lexington, Massachusetts.

3.1.1 Ground Facilities

DABSEF contains an experimental DABS monopulse sensor which provides DABS and ATCRBS surveillance reports at an update rate of once every four seconds. The IPC algorithms reside in the DABS sensor real time control computer, a systems Engineering Laboratories SEL-86 (Fig. 3-1). During each mission, surveillance reports are displayed upon a TPX-42 traffic situation display (Fig. 3-2). Two cockpit display monitors, identical to the IPC display units mounted in the aircraft, display the IPC messages for the current scan. IPC algorithm computations are simultaneously displayed upon a CRT conflict display. An intercept control algorithm resident in the SEL-86 provides intercept information to the test aircraft cockpit via the DABS uplink, and is also presented alphanumerically on the SEL real time display. All significant DABS/IPC link activity and algorithm computations are recorded on magnetic tape for post-flight analysis, and all voice communications with the pilots

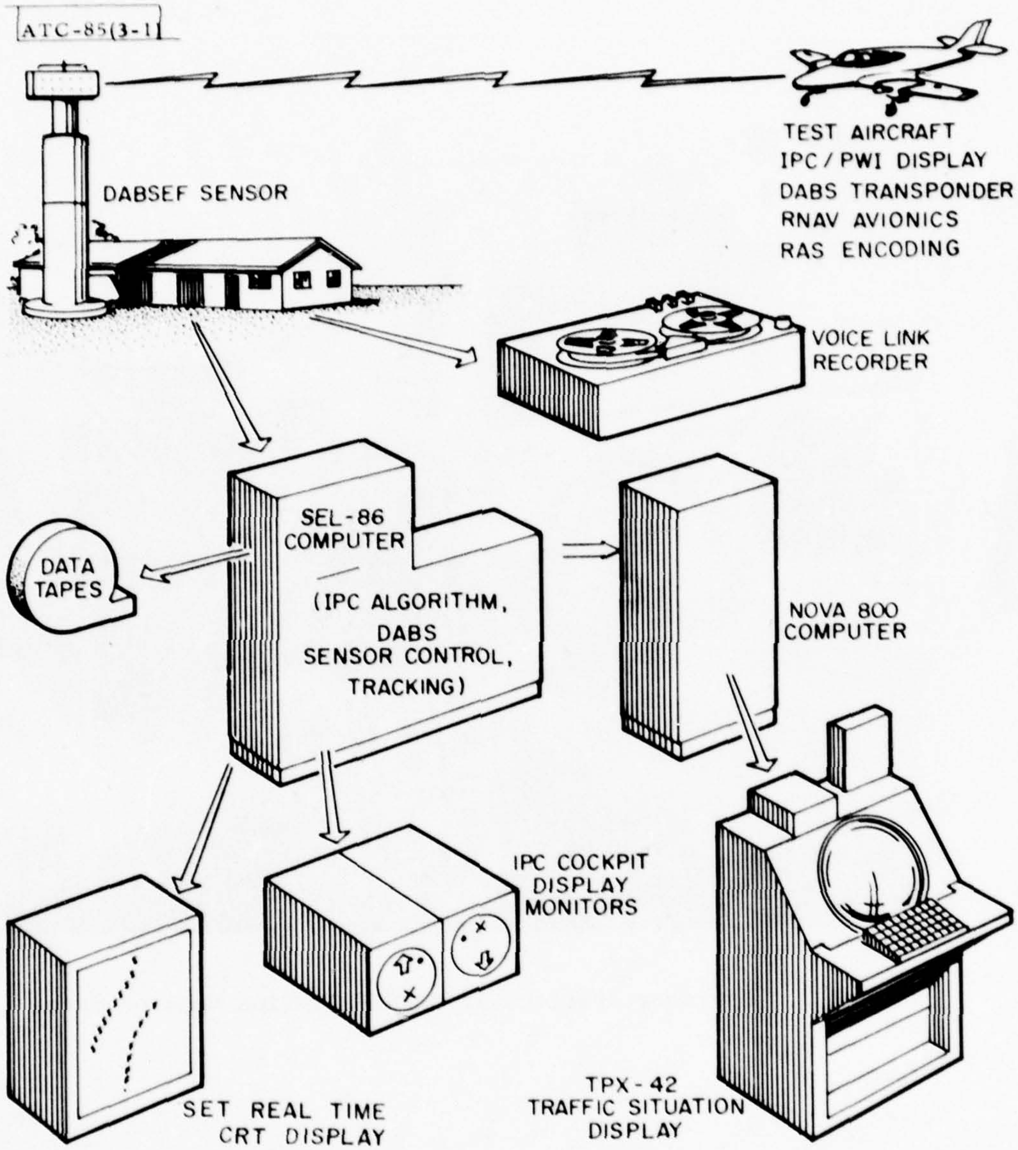

Fig.3-1. IPC test bed facility at the DABS Experimental Facility (DABSEF).

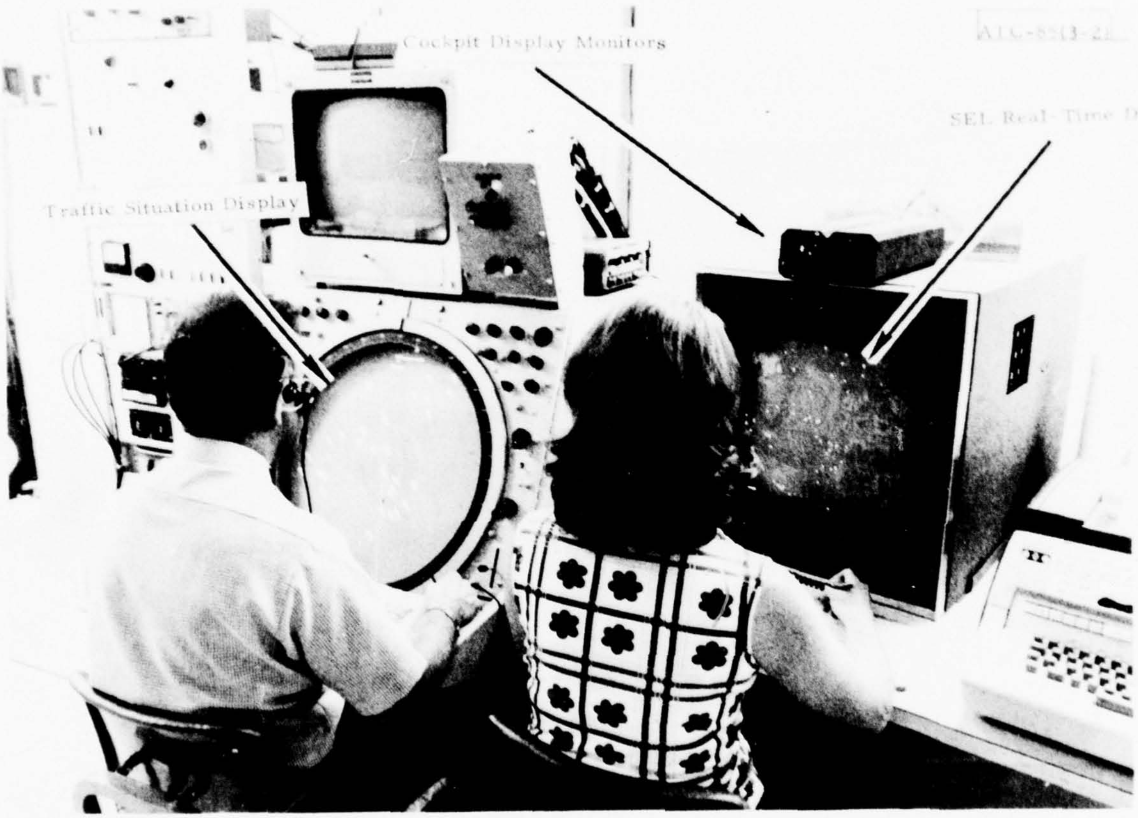

Fig.3-2. Operator stations in DABSEF Mission Control Room.

are recorded on audio tape. This audio tape can be synchronized later with a playback of the digital data tapes in order to recreate the control room situations observed during the mission.

3.1.2 Test Aircraft

The test program utilized primarily single engine general aviation aircraft*. A Cherokee Six or a Beech Bonanza F-33 was employed as the interceptor aircraft. A Cherokee 180 or Cessna 172 was normally used as a drone. The higher available speed of the interceptor aircraft allowed it to more readily achieve positions required for successful intercepts. Many of the subject pilots were unfamiliar with the constant speed/variable pitch propeller of the Cherokee Six and were more comfortable flying the lower performance aircraft.

The test aircraft were equipped with a DABS transponder, an IPC display and a standard ATCRBS transponder (Fig. 3-3). RNAV was installed so that the planned intercepts could be conducted at selected waypoints independent of the VOR and Victor route airways. The VHF communication system was modified to allow independent transmit/receive operations at either the pilot or co-pilot positions. An alphanumeric display was installed to provide the interceptor with intercept information as computed by a special purpose intercept control algorithm. The intercept technique developed for use with this display is discussed in Section 3.2. The test aircraft were also instrumented to downlink on the DABS data link certain aircraft attitude information from special on-board sensors.

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*A Lockheed C-140 Jet Star was utilized in a single mission to investigate the feasibility of conducting higher speed intercepts.

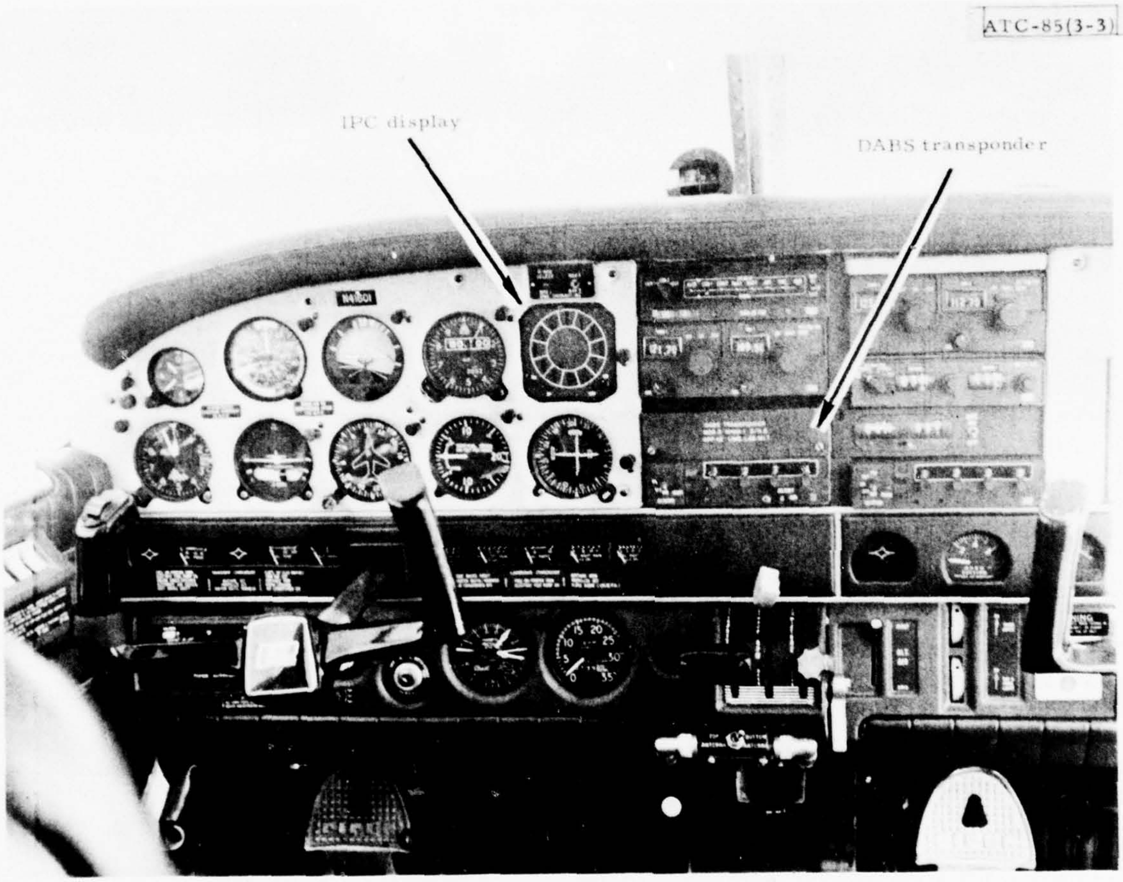

Fig. 3-3. Cherokee Six cockpit as configured for IPC flight tests.

The equipment which permitted downlinking this information was called the Readout of Aircraft State (RAS) system. The special DABS avionics package is sketched in Fig. 3-4. Aircraft were equipped with strobe lights which were operative at all times.

3.1.2.1 Data Reduction Capabilities

A set of software analysis routines (Fig. 3-5) are used following a mission to process the recorded data in order to produce plots and tabulated results for each conflict situation. These outputs are available after a mission and are used in debriefing the pilots. Mission data summaries are compiled to provide a record of each encounter flown on a scan by scan basis. The data base capability provides for the storage and retrieval of selected information on each encounter. Data is available for all encounters flown during the flight test program. The data includes information on pilot history, mission log, tracking and IPC algorithm variable values during an encounter. The data may be plotted on a CRT graphics terminal and retained as hard-copy output.

3.2 Test Methodology

3.2.1 IPC Flight Test Missions

Three types of IPC flight test missions were flown. Missions involving test pilots flying both test aircraft were scheduled to exercise IPC logic with pre-determined approach paths and pilot responses. These missions were designated validation missions. They provided valuable insight into the behavior of the logic, and allowed investigation of many logic problem areas in which testing with subject pilots was not advisable. The validation tests

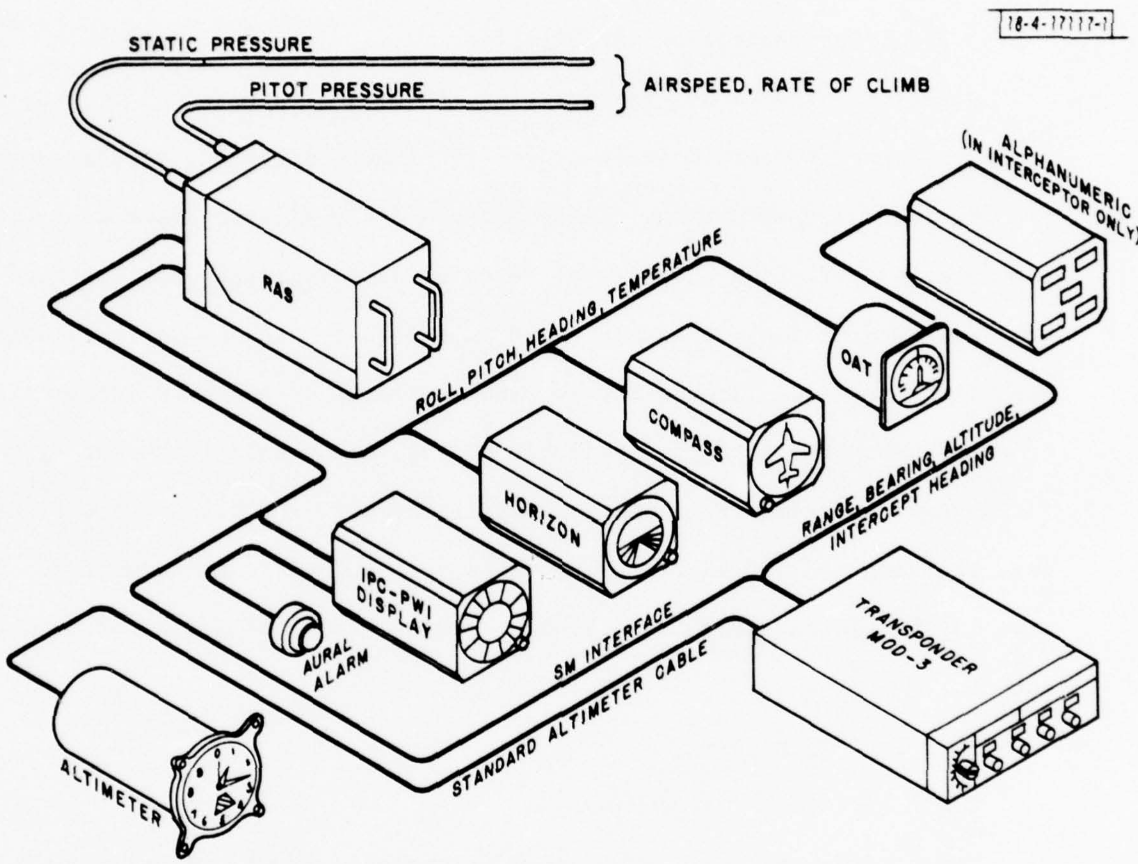

Fig. 3-4. Special DABS avionics for IPC, intercept control, and data collection.

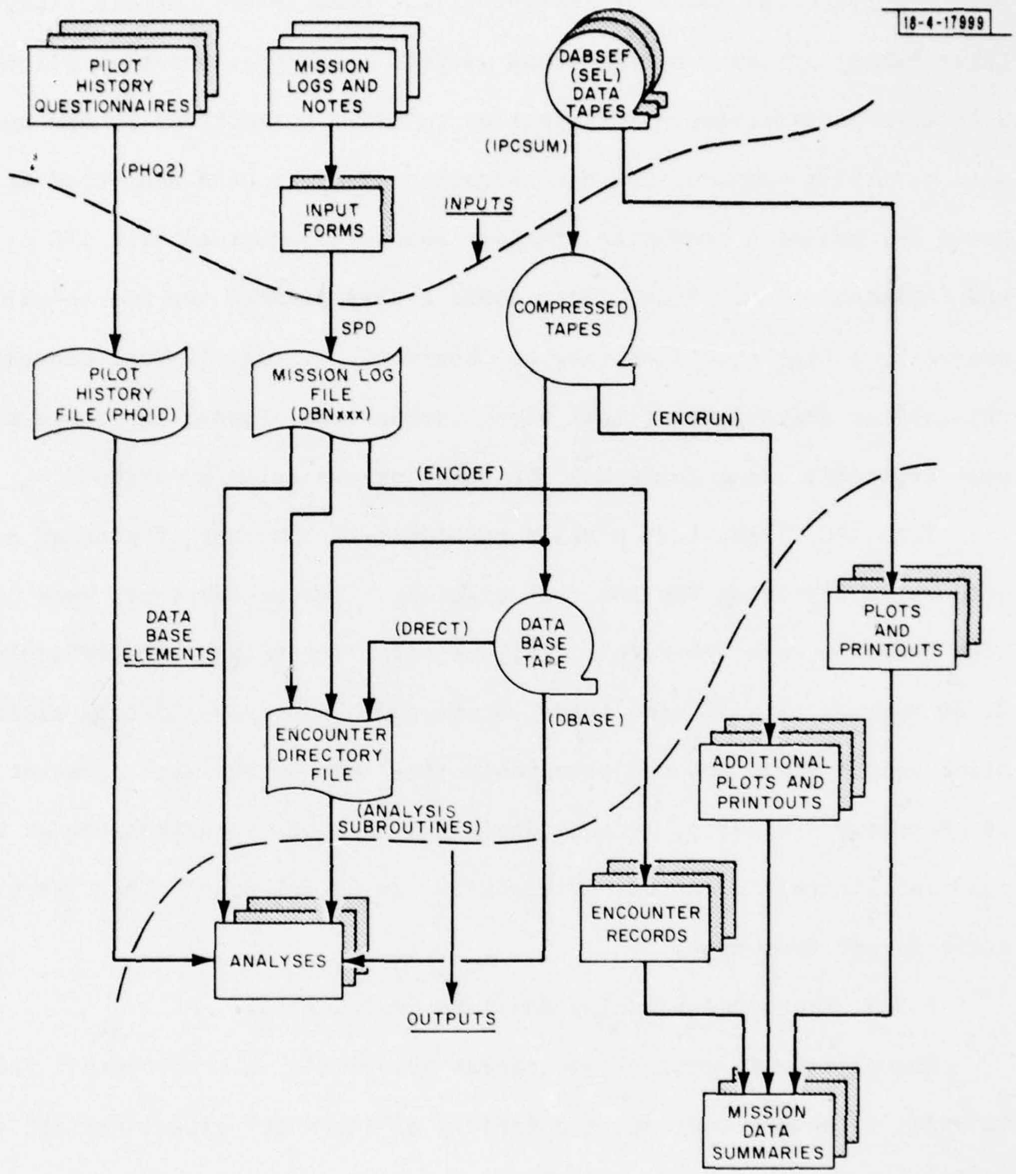

Fig.3-5. IPC data reduction flowchart.

were the principal basis of the IPC flight test interim report (Ref. 5). Later tests involving a wide cross section of general aviation pilots were scheduled to determine pilot reaction to IPC. In addition to the normal data gathering mission, IPC demonstration missions were scheduled on an ad hoc basis for aviation community visitors who were concerned with IPC development and implementation. These individuals either piloted the drone (while accompanied by a test pilot) or flew as observers. These missions generally utilized an abbreviated flight plan. Encounters planned for these missions were typically those for which IPC behavior was fully understood.

Each IPC flight test mission consisted of a number of planned near-miss encounters involving the two test aircraft. Two missions per week of two hour duration were scheduled. Subject pilot encounters were scheduled to occur at an average rate of once every 10 minutes. During validation missions, where pilot reaction was not the prime objective, encounters were flown at the rate of one every 5 minutes. Random unplanned encounters between one or both of the test aircraft occurred occasionally due to itinerant ATCRBS Mode C aircraft in the test area.

3.2.3 Encounter Planning and Intercept Control

The ability to control the characteristics of IPC encounters was required in order to ensure testing of a variety of encounter situations and to efficiently reproduce situations for which a greater quantity of data was desired. Certain variables were either not under test control or could not readily be included in test planning. Table 3-1 lists planned and unplanned

TABLE 3-1

IPC ENCOUNTER VARIABLES

Planned:		Unplanned:
Flight rules	(IFR,VFR)	Subject pilot response
Equipment	(DABS, ATCRBS)	Itinerant ATCRBS traffic
Aircraft type	(high wing, low wing)	Visibility
Speeds		
Crossing Angle		
Miss Distance		
Approach Type	(straight & level, turning, climbing, descending)	
Test pilot response		

TABLE 3-2

IPC FLIGHT TEST PROGRAM STATISTICS

MARCH 1975 - FEBRUARY 1977

Missions	132 Total	Pilots	79 Total
Validation	61	Test	5
Demonstration	20	Demonstration	17
Subject pilot	43	Subject	57
ENCOUNTERS	1603 Total		
Planned	1419		
Unplanned	184		

encouter variables. It should be noted that when aircraft were designated as IFR, they were in reality being flown as VFR by a test pilot and were not under control by an ATC facility. The IPC algorithm however treated them as if they were truly IFR.

It was found early in the testing that the degree of precision required in order to conduct intercepts which consistently resulted in near-miss approaches was not easily obtainable. One reason for this is that it is unacceptable for aircraft to continue to make course corrections until IPC commands appear since these corrections induce tracking lag and do not allow characterization of IPC performance for typical non-turning encounters. To test non-turning performance, aircraft must be stabilized on appropriate courses several scans before the IPC logic begins to alarm. Navigation by landmarks or VOR's proved inadequate to achieve the desired intercept precision. A control procedure was adopted which required the drone to fly a given path while the interceptor was provided intercept data based upon DABS position reports. This data included the drone altitude, relative bearing, and the heading correction required to achieve a zero miss distance intercept. This information was transmitted automatically over the DABS data link and displayed to the interceptor pilot on an alphanumeric intercept control display. This control technique proved to be highly effective.

3.2.4 Subject Pilot Methodology

In order to obtain valid insight into pilot response to IPC, a variety of general aviation pilots were selected to serve as test subjects. The DOT

Transportation Systems Center provided a list of pilots who had served as subjects in a previous simulation study of PWI. This list was augmented by other pilots referred by various sources. A few pilots were air carrier or military professionals who flew general aviation aircraft only for pleasure. Selected pilots who accepted the invitation to participate were given an indoctrination lecture on IPC and the flight test program. They were given literature prepared specifically for pilots (Ref. 6). The literature covered the conduct of the tests and the role the prospective subject pilot was expected to play. Initially check flights in the instrumented test aircraft were given the subjects to familiarize them with the aircraft, their expected duties and what to expect from IPC. It was later decided these check flights were unnecessary so long as care was taken that pilots fly only aircraft types with which they were familiar. Two pilots were scheduled to fly on a given day. A pre-briefing was given to review the literature distributed during the indoctrination lecture. For most missions this briefing was conducted by the MITRE Corporation representative who had authored the IPC Pilots Handbook (Ref. 6). An IPC cockpit display was exercised with manually controlled inputs to familiarize the pilots with the visual and aural alarms they would receive in the cockpit.

The typical subject pilot mission consisted of two separate flights. The first involved one subject pilot flying a high-wing aircraft for an hour. The second involved the other subject flying a low-wing aircraft for the next hour. The drone aircraft piloted by a subject always carried a test pilot in

the right seat. The interceptor was flown by a test pilot with an observer in the right seat. The encounters flown were selected to provide the subject pilot with a range of typical conflict conditions. The subject pilot's workload was comparable to the normal workload except for the addition of the IPC display functions. The subject flew a pre-briefed course, changing headings and altitudes according to a pre-arranged plan. A monitor on the ground was in voice contact with the subject recording comments and reaction to each of the IPC stimulae. The subject was encouraged to discuss each situation throughout the encounter. This aided the pilot later in recalling each encounter since his memory could be stimulated by the phrases and descriptions used at the time of the event. As one subject pilot returned to base, a head-on intercept with the other subject aircraft was usually staged without either subject pilot being forwarned. Following each mission the pilots were debriefed. They were encouraged to expand on their airborne comments and discuss each situation in detail. Plots and data for each encounter were used as needed to refresh the pilot's memory and clarify comments. Pilots were given questionnaires to fill out and return by mail in order to obtain their final overall reaction to the IPC flight test experience.

3.3 Test Activity Summary

3.3.1 Encounter Statistics

Over 80 pilots participated in the evaluation of IPC as test, demonstration or subject pilots (Table 3-2). The 132 missions include over

1600 conflict situations. About 10 percent of the encounters were unplanned, occurring as one or both of the test aircraft encountered itinerant ATCRBS aircraft.

It was important to explore in the flight test program the impact that varying transponder equipage and flight rules had on the conflict resolution. The algorithm sets thresholds and varies resolution strategy on this basis. The majority of planned encounters involved two DABS equipped aircraft (Fig. 3-6). The unplanned encounters were of special interest since they were unstaged and sometimes involved air carrier or military aircraft.

3.3.2 IPC Algorithm Revisions

The IPC algorithms underwent a number of revisions during the two year flight test program (see Table 3-3). These revisions took the form of changes to the logic to correct faults which prevented the logic from functioning as specified by the IPC concept (ex. M-S1, M-S12, and M-S15). Some revisions were intended to resolve design problems identified during flight testing (ex. M-S7, L-S1, and L-S2). None of these revisions constituted a fundamental change in the orginal concept or design. The number of missions flown with each version is indicated in Table 3-4.

ATC-85(3-6)

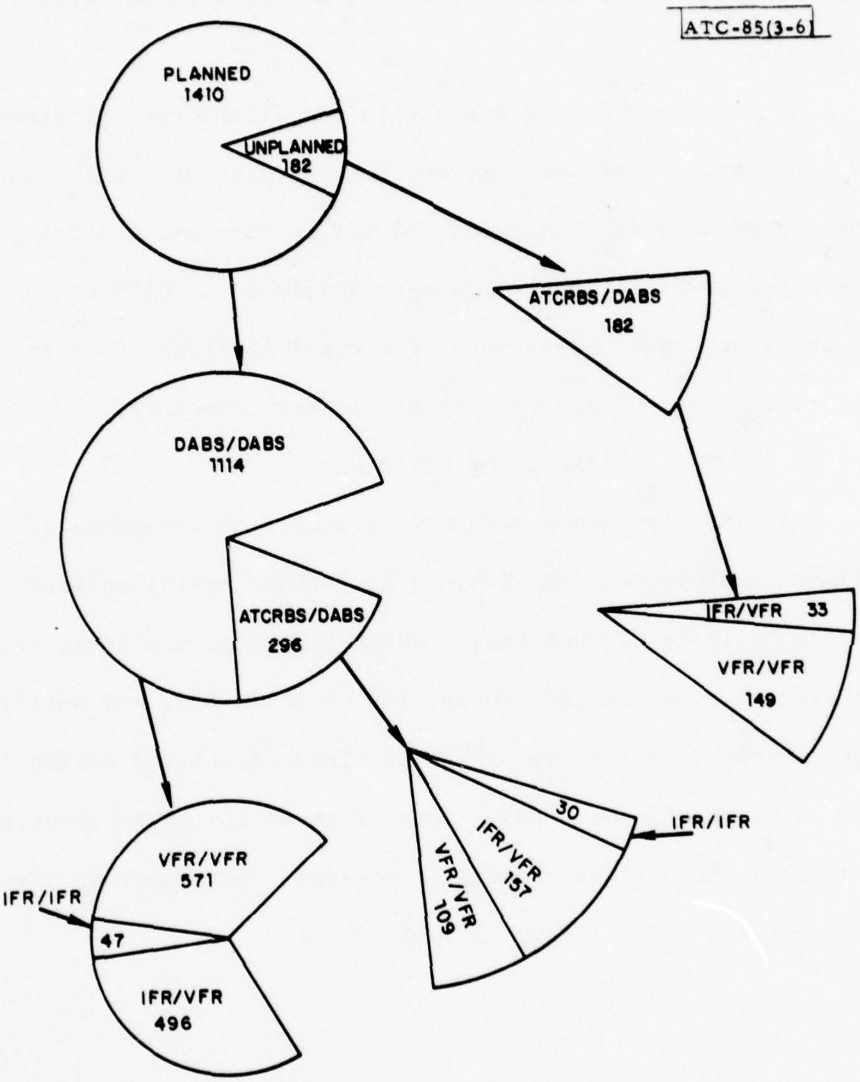

Fig. 3-6. Characteristics of the IPC encounters for which data was collected.

TABLE 3-3

REVISIONS OF THE IPC TEST BED ALGORITHM

Algorithm Version	Test Algorithm Designation	Change Proposal Designation	Major Revisions Incorporated in Version
0	LTAC-0		None (initial shakedown version)
1	LTAC-1		Linked list coarse screening technique.
			Minimum 2 mile PWI range threshold to alleviate wind effects on threshold.
			DOT test to drop commands sooner.
			Modified tau (TH) to achieve more uniform rate of tau decrease.
			Command selection Rule C to avoid ineffective Rule A commands.
			Separate maximum firmness level for vertical tracking to increase responsiveness of tracker.
2	LTAC-2	M-S1	Reduce false alarms - unnecessary commands, flashing PWI's and controller alerts.
		M-S2	Eliminate commands dropping before resolution complete.
		M-S3	Commands computed for IFR aircraft and delivery delayed.
		M-S5	Eliminate acknowledgement test for VFR ATCRBS.
3	LTAC-3	M-S6	Revise IFR/VFR logic to reduce unacceptable number of positive commands to IFR.
		M-S7	Reduce number of positive commands when a vertical rate is present.
			Eliminate vertical chase problem with ATCRBS/DABS encounters.

TABLE 3-3 (Continued)

Algorithm Versions	Test Algorithm	Change Proposal Designation	Major Revisions Incorporated in Version
4	LTAC-4	M-S12	Reduce number of controller alerts for IFR/VFR encounters.
		M-S15	Reduce undesirable positive commands due to vertical velocity jitter.
		M-S16	Reduce number of positive commands by giving negatives whenever situation dictates.
		L-S1	Provide additional command to DABS in DABS/ATCRBS when DABS does not acknowledge.
		L-S2	Install general purpose audio alarm.
5	LTAC-5	FAA-EM-74-4 Rev 2 (single Site Version)	Incorporateds all the previous revisions in a single volume.

TABLE 3-4

CLASSIFICATION OF IPC FLIGHT TEST MISSIONS

FLOWN WITH EACH VERSION OF ALGORITHM

March 1975 - February 1977

Algorithm Version	Validation	Demonstration	Subject Pilot	IPC Missions Total
1	30	9	14	53
2	1	1	3	5
3	7	4	8	19
4	9	8	18	35
5	13	4	1	18
	60	26	44	130

4. ALGORITHM VALIDATION

The algorithm logic which evaluates collision threats and selects avoidance messages is a critical element of the IPC design. This logic must provide effective protection over a wide range of encounter situations. Its success rate must be high, since pilot acceptance of the system will be adversely affected if the logic fails to provide acceptable results in a noticeable number of cases. In this section we will address the ability of the IPC logic to achieve its stated control objectives of assuring safe separation with minimum disruption of normal flight. Logic validation issues were investigated primarily in flights involving test pilots who were instructed to obey IPC commands. The tendency for the instructions of the IPC system to conflict strongly with the desires of subject pilots, and the possible compromise of the control strategy by the pilots' refusal to comply, are topics which are addressed in the section on pilot utilization (Section 5).

The performance of the IPC system varies greatly with the dynamics of the encounter. Diagnosis of this behavior and generalization from specific encounters requires a sound understanding of collision avoidance dynamics. This is especially true when the question at hand involves two or three dimensions rather than just one. For these reasons a technique for the analysis of the relative motion of aircraft was developed and it has proven to be very useful in interpretation of test results. An introduction to the terminology employed in the analysis is provided in Figs. 4-1 and 4-2.

Relative Motion - The collision avoidance problem is formulated in terms of a dynamic system which describes how aircraft move relative to each other.

State Variables - Horizontal relative motion is described in terms of five state variables: horizontal range (r) between aircraft, the relative bearing (β_1 and β_2) of each aircraft from the other, and the airspeeds (V_1 and V_2) of each aircraft. Bearing is measured positive clockwise from the velocity vector of the aircraft of interest. It is expressed as a number beween -180^o and $+180^o$. These variables are depicted in Fig. 4-2.

Normalization - For plotting purposes it is convenient to express distances as a fraction of range and velocities as a fraction of V_1 (the airspeed of the faster aircraft). Times will be expressed in units of r/V_1.

Speed Ratio - The speed ratio is the ratio of the airspeed of the slower aircraft to that of the faster. (e.g., V_2/V_1).

Natural Motion - Refers to the type of motion which results from unaccelerated (rectilinear) flight.

(Signed) Miss Distance, m - The miss distance, MD, used in IPC is the minimum range which would result from pure natural motion projected forward or backward from the current time. For analytical purposes it is convenient to define a signed miss distance, m, whose magnitude is the same as MD, but whose sign is positive if the range vector is rotating clockwise and negative if the range vector is rotating counter clockwise.

Forced Motion - Forced motion is the type of motion which would result from an instantaneous change in heading (thus producing a corresponding instantaneous change in bearing). In Appendix A it is shown that actual aircraft trajectories can be represented as a combination of natural and forced motion.

Fig. 4-1. Synopsis, relative motion analysis technique.

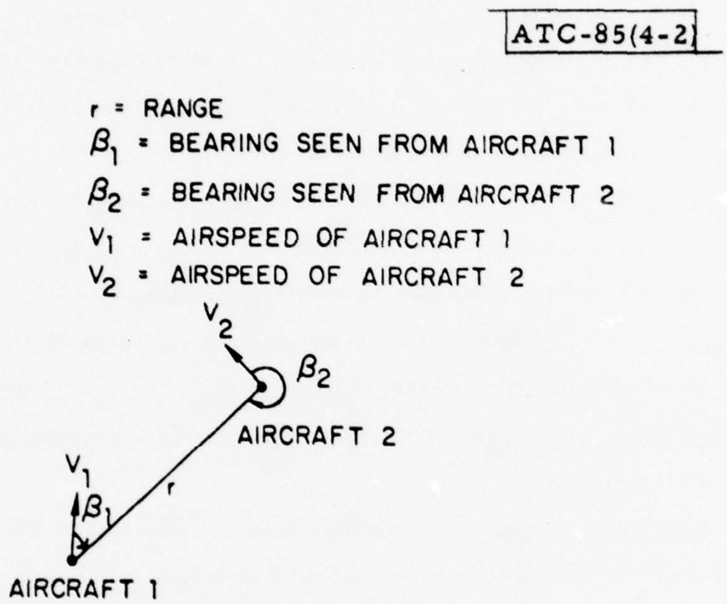

Fig.4-2. Variables utilized in relative motion analysis.

A more complete discussion of the technique is provided in Appendix A. It is recommended that the reader desiring full understanding of the methods by which IPC has been analyzed consult this appendix when necessary while reading the remainder of Section 4.

4.1 Trajectory Estimation

Accurate estimates of aircraft positions and velocities are required in order for a collision avoidance system to function effectively. The IPC system bases its estimation of these trajectory variables upon DABS position reports which are received at the nominal rate of once every 4 seconds. These reports provide the range and azimuth of the aircraft relative to the DABS sensor and provide the aircraft barometric altitude as encoded by the aircraft altimeter. Higher derivatives of position (i.e., velocities and accelerations) must be inferred from observation of the time history of position reports. The portion of the algorithm which estimates aircraft trajectories is called the IPC tracker. The finite DABS data rate and the inherent errors or uncertainties in the DABS position reports limit the accuracy with which aircraft trajectories can be determined. A further limitation arises because the tracker design must be based upon a simplified model of aircraft dynamics. The IPC tracker is designed to minimize the effects of random data errors and to accommodate typical aircraft dynamics. The performance figures for horizontal tracking are largely based upon Ref. 11, and the reader is referred to that document for further detail.

4.1.1 Trajectory Estimation With Nominal Surveillance Quality

Description of IPC Tracking Algorithm

The IPC tracking algorithm is basically a low gain α-β tracker with a turn detection and correction mechanism. The low value of β (0.1) provides heavy suppression of scan-to-scan measurement jitter during straight-line flight. In order to prevent the excessive heading lag which such heavy smoothing would normally engender during turns, the turn correction mechanism adds heading corrections which force the heading in the direction of detected turns. Turns are detected by noting deviations of aircraft reports from the predicted flight path.

Nominal Tracking Performance

The performance of the tracker depends upon (1) the nature of errors in the position measurements, and (2) the acceleration history of the aircraft being tracked. The position measurement errors which are most significant to IPC are those which vary from scan to scan and thus induce errors in the velocity estimates. Nominal magnitudes of these errors at DABSEF are approximately 15 feet (1σ) in range and .05 degrees (1σ) in azimuth. For aircraft in straight line flight these accuracies allow the current IPC tracker to estimate heading with an error of 3 degrees (1σ) and speed with an error of 2 knots (1σ). These accuracies are more than adequate for collision avoidance purposes.

The accuracy of heading estimates during turns is a function of aircraft speed, turn rate, and the ability of the tracker to promptly and consistently declare turns. At typical turn rates (3-5 deg/sec), heading errors of 30 or 40 degrees are to be expected. The impact of these errors upon IPC performance is discussed in Section 4.5.

During a turn the tracker tends to underestimate aircraft speed. At turn rates of 4-5 deg/sec the speed error is typically 15% of the aircraft total speed.

Turn Detection Failure

In order to prevent false turn declarations due to jitter error in position measurements, the turn detection thresholds are adjusted in accordance with track firmness* and expected cross-track measurement accuracy. At longer ranges these thresholds may increase to a significant fraction of the turn radii of slower aircraft. When this happens, turns can remain undetected until after aircraft have turned 90° or more from their initial headings. Heading errors of this magnitude prevent the cross-track tests of the turn detection logic from functioning properly since the estimated cross-track direction is grossly misaligned with respect to the actual cross-track direction. In some flight test encounters heading errors of 120° and airspeed errors of 2/3 actual airspeed were observed (see Example 1 Appendix C). These difficulties may be amenable to solution by allowing the tracker to recognize when turn detection is likely to fail and to increase tracking gains accordingly.

Wind Effects

The IPC tracking algorithm does not take wind into account in estimating aircraft headings and airspeeds. All velocities are estimated with respect

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*The tracking gains to be used are specified in terms of a firmness level. The firmness level is a function of the recent history of successful report-to-track correlations.

to the sensor as ground reference. When the airmass in which the aircraft are flying is in motion, the velocity of the aircraft with respect to the ground may differ significantly from the airspeed. If it is assumed that each aircraft is subject to the same wind, then all relative motion quantities which depend only upon distances and the velocity differences (e.g., tau and miss distance) will be unaffected by the wind. But other quantities will be modified by wind (e.g., crossing angle, speeds, time to path crossing). For slower aircraft flying in strong winds the errors in estimating these latter quantities can be significant. Consider for instance two 100 knot aircraft, one flying parallel and one flying anti-parallel to a 40 knot wind. The actual airspeed ratio is unity while the tracked speed ratio (i.e., groundspeed ratio) is 140/60 = 2.3. Depending on magnitude and orientation, wind can change the value of warning thresholds, the choice of maneuver plane, and the directions of horizontal commands. Wind has been observed to aggravate the problem of tracking turning aircraft since aircraft turning downwind seem to increase speed while those turning into the wind seem to decrease speed. One algorithm modification to decrease sensitivity to wind was made during flight tests. The Version 0 algorithm had an OPWI threshold that was a function of squared speeds. It was discovered that when two slower aircraft were flying into strong headwinds their low observed speeds resulted in late issuance of OPWI. For this reason the algorithm was modified to issue OPWI's whenever range decreased below 2 miles.

It is recommended that the ability to study wind effects be included in future IPC simulation efforts and that the feasibility of making wind corrections to velocity estimates be considered.

4.1.2 Observed Effects of Surveillance Anomalies

Flight tests have revealed certain errors which have received little attention in IPC system design, but which can adversely affect performance. These error sources are listed here so that future system development can proceed in awareness of their existence.

Azimuth Anomalies

The accuracy of the aircraft azimuth measurement can be affected by conditions which arise intermittently on isolated scans (e.g., asynchronous interference). One often observes a sequence of many scans of highly accurate azimuth reports which contain an isolated anomaly corresponding to a substantial measurement error. This anomaly can perturb the track significantly and the perturbation may require several scans to subside. The α-β smoothing technique is well suited for suppression of errors which are scan-wise independent but is less well suited for suppressing the effect of isolated anomalies. A carefully designed outlier rejection scheme based on acceleration reasonableness should be implemented to improve performance in this area.

Diffraction Effects Near Obstacles

ATC beacon radars estimate target azimuth by determining the orientation of the signal wavefront of the target reply. Phenomena which perturb the wavefront orientation must necessarily result in errors in target azimuth estimate. One such perturbation which may have a serious impact upon IPC performance when it occurs is azimuth error due to signal diffraction around obstacles. Two major obstacles exist at DABSEF. The first, an antenna tower, is located at an azimuth removed from the usual IPC flight test area. The second, the smokestack of the Hanscom Field power plant, is located be-

tween the DABSEF antenna and the IPC test area at an azimuth of 295.9^{o} and at a range of about 1500 feet. Several IPC encounters which occurred at low elevations in the vicinity of the smokestack azimuth resulted in resolution failure due to errors in estimated azimuth. Example 2 in Appendix C is a particularly severe case. The diffraction phenomenon is well understood from both experimental and theoretical points of view (Ref. 8). The error is known to vary as a function of obstacle size and angular separation between the target and obstacle. Currently most terminal ASR's are sited in locations for which diffracting obstacles are present on the horizon. Aircraft flying near the horizon and near obstacle azimuths cannot be processed by IPC in the same manner as aircraft flying in the clear. Improved siting of DABS antennas may go far to alleviate the diffraction problem at some locations, but the basic problem will never be completely eliminated and must be recognized in IPC system development.

Vertical Tracking With Missing Reports

It was discovered in testing the Version 0 algorithm that tracking gains used for horizontal tracking produced excessive lag and overshoot in vertical tracking. Vertical tracking has no logic equivalent to the turn detection logic which makes low gains tolerable for horizontal tracking. Consequently, the Version 1 logic specifies that the firmness level for vertical tracking is never to increase above 7. From this level even two missing replies can cause firmness to decrease to a level at which highly erroneous altitude rates can be induced. As an example consider an encounter for which the initial tracked altitude rate is zero and the initial firmness level is 7. A series

of two missed replies reduces firmness to level 3 at which level the tracking gains are α = .833 and β = .700. If an altitude report which differs by ΔZ = 100 feet from the coasted altitude is then received, the altitude rate is modified by

$$\frac{\Delta Z}{T}\beta = \frac{100 \text{ ft}}{4 \text{ sec}} 0.7 = 1050 \text{ fpm}$$

But the 100 foot decrease in altitude may well be due to altimeter quantization or to track coasting which occurred during the periods of missing data. Example 3 of Appendix D provides a case in which a vertical climb rate of almost 1500 fpm was estimated when the aircraft was actually slowly descending. If reports are uncorrelated due to erratic altimetry the errors can be even worse.

Vertical Tracking Lag

When changes in altitude rate occurred, the vertical tracking often responded much more slowly than can be justified by smoothing considerations. This lag could result in late commands or persistence of commands after resolution was assured (see Example 4 in Appendix C).

4.2 Conflict Filtering

The IPC conflict filtering logic consists of three parts: (1) coarse screening which identifies from the track file aircraft pairs which may be in hazardous proximity and which should be subjected to further processing, (2) threshold selection logic which selects tau and miss distance alarm thresholds based upon the attributes of the aircraft pair and (3) a detection logic which tests computed detection variables against the thresholds to determine the type of IPC messages (OPWI, FPWI, commands, etc.) to be issued.

4.2.1 Coarse Screening Logic

The coarse screening portion of the IPC logic is intended to identify in a computationally efficient manner those aircraft for which IPC detection variables (e.g., tau) are to be calculated in the alarm flag logic. The initial IPC coarse screening algorithm utilized a sort bin technique for screening. This method suffered from a need to process a large number of empty bins each scan. It was replaced in Version 1 by a more efficient linked list approach. This list is ordered according to increasing x coordinate and the number of entries is essentially equal to the number of aircraft being serviced.

During flight tests several cases were observed in which aircraft in close proximity failed to pass coarse screening. This condition usually arose abruptly during an encounter and resulted in IPC terminating service at a critical moment. The source of the problem lay in the fact that the coarse screening algorithm searched the linked list in one direction only* and processed aircraft according to azimuth sector. If two conflicting aircraft in adjacent sectors changed order between the time their respective sectors were processed then the unidirectional scan failed to detect the pair. In order to allow IPC testing to proceed, the DABSEF version of the algorithm was modified to eliminate the problem. The analogous modifications which were specified later for Version 5 were not flight tested.

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*This search technique provides a method of reducing the required computational load. The algorithm can discover that aircraft A is in proximity to aircraft B without the redundant processing associated with the discovery that aircraft B is in proximity to aircraft A.

4.2.2 Alarm Threshold Transitions

No documentation has been provided which explains the choice of each threshold determining attribute and its corresponding threshold, but the basic design philosophy involves increasing thresholds for attributes which indicate greater difficulty in resolution and increasing thresholds for VFR aircraft in conflict with IFR aircraft. In many cases this logic produces discontinuous jumps in threshold values even when tests are based upon continuous variables. For example, when the speed of an ATCRBS aircraft is more than 1.5 times the speed of the DABS aircraft, the command threshold jumps from 32 to 64 seconds. These transitions can occur at any time during an encounter and result in an abrupt change in the alarm status of the aircraft.

Aspects of the encounter geometry which affect urgency are not among the encounter attributes considered in the threshold selection logic. For example, miss distance and crossing angle are not considered. Thus alarm declarations at consistent levels of urgency are not possible.

4.2.3 Tau Criterion

For zero-miss rectinlinear approaches the time until collision can be expressed in terms of range and range rate as $\tau = -r/\dot{r}$. But in this form τ is not reliable as a measure of urgency since low closure rates can cause τ to remain high regardless of range. The IPC algorithm therefore uses a modified form of this measure which may be written

$$TH = \frac{-r}{\dot{r}}\,(1-D^2/r^2)$$

Here D is a parameter with a nominal value of approximately 0.5 nmi. It can be seen that TH will be forced to zero at range D no matter how small the closure rate. In testing Version 0 of the algorithm it was found that excessive turns could result from continuing commands to aircraft which were within range D but were separating. For this reason the "DOT" test was added to the detection logic. This test prohibited any horizontal threshold from being violated if the product of range and range rate exceeded 10 nmi-knot. (A threshold value of 1.0 nmi-knot was first proposed, but was found to result in deletion of needed commands).

At large crossing angles TH is relatively insensitive to tracking errors and accelerations since velocity errors are then small compared to the magnitude of $\dot{r}$ and aircraft accelerations due to turns are mostly normal to the range vector. But for aircraft of similar speeds approaching at smaller crossing angles, TH can be very sensitive to errors and accelerations. In some cases this sensitivity can result in confusing transitions in the alarm level (Fxample 5 in Appendix C) or rapid crossing of several tau thresholds (Example 6 in Appendix C). The latter phenomena is important since several aspects of the IPC concept (e.g., PWI warning time before commands, time allowed before compliance check) apparently require that TH decrease at the same rate as clock time so that TH thresholds which differ by a given amount will be violated at times which differ by the same amount. In reality, even with constant closure rates TH decreases more rapidly than clock time due to its nonlinear dependence upon range. Furthermore, in many encounters there

is some condition which produces small but definite increments in estimated closure rate. For instance, the aircraft may not be flying perfectly straight or the tracked heading may be converging to the current heading in order to eliminate a heading error which arose earlier. More severe increments occur when one of the aircraft is deliberately turning. Under these conditions TH values reflect neither the actual passage of time nor the actual time to collision. Further discussion of the effect of accelerations upon IPC performance can be found in Section 4.5.

4.2.4 The 2/3 Command Flag Logic

IPC does not issue commands unless the command flag (CMDFLG) has been set on two of the last three scans. This "2/3 logic" is primarily intended to prevent unnecessary commands in situations where a turning aircraft is coming into momentary conflict with nearby traffic as its velocity vector sweeps through a range of headings. But this logic imposes a one scan delay in command issuance for all encounter situations. In some cases the trajectory information indicates a severe hazard which can only be made worse by the existing accelerations, and the algorithm does not react until the next scan when the command flag is set for the second time. This single scan of delay is most significant when aircraft are accelerating in a manner that produces late commands. More timely IPC intervention could be obtained if commands were delayed only when the trajectory estimates were consistent with the hypothesis that the command thresholds would not be violated on the next scan.

4.3 Choice of Resolution Plane

In most situations the initial attempt at conflict resolution involves commands exclusively in the horizontal plane or the vertical plane. The choice of the plane to be used may determine the success of the resolution attempt. In IPC this choice is based upon certain characteristics of the encounter. Several cases were observed in which the original IPC algorithm made a poor choice of the maneuver plane and revisions to the logic were implemented to address these cases.

The Version 1 IPC algorithm would occasionally issue positive commands in the vertical plane even though negative commands in the horizontal plane would have been sufficient. In Version 4 logic was added which assured that the resolution plane which required only negative commands would be selected whenever such a plane existed. But this logic is exercised only upon initiation of resolution. At a later time it is still possible for a negative command to transition to a positive command in the same plane even though a negative command in the other plane would be adequate (see Example 7 in Appendix D).

It was observed in flight tests that when an uncommanded aircraft possesses a vertical rate toward a DABS aircraft, issuance of vertical commands to the DABS aircraft may be ineffective. The vertical rate of the uncommanded aircraft may cancel the rate achieved by the commanded aircraft (the vertical chase problem). Even when the commanded aircraft is able to respond at a greater rate than the threat, it may be forced to climb or descend through an excessive distance. The Version 3 logic added a provision for requiring

horizontal resolution whenever an uncommanded aircraft has a vertical rate of ZDTH (360 fpm) or greater in the direction toward the DABS aircraft at the time of command generation. This change has proven only partially successful since the algorithm may still issue and sustain ineffective vertical commands if the estimated vertical rate of the uncommanded aircraft does not exceed ZDTH until after commands are generated (see Examples 8 and 9 of Appendix D).

In Version 1 vertical commands were chosen whenever one aircraft of the pair had a speed greater than 150 knots. This logic was based upon certain assertions concerning the relative effectiveness of horizontal and vertical commands for aircraft of varying performance levels. Initially this logic would issue vertical commands to a slow DABS aircraft in conflict with an ATCRBS aircraft of groundspeed 150 knots or greater. This logic was altered in Version 3 to apply the speed discriminant to commanded aircraft only.

4.4 Horizontal Resolution for Non-accelerating Encounters

4.4.1 Effects of Dissimilar Speeds

Special considerations arise when an attempt is made to resolve an encounter between aircraft of greatly differing speeds by maneuvering only the slower aircraft. First, a given heading change by the slower aircraft is less effective in altering miss distance than a similar heading change by the faster. In certain geometries modest heading changes by a faster aircraft can negate the avoidance attempts of the slower (see Example 10 in Appendix C). Furthermore, there is a heading for the slower aircraft which results in maximum miss. If an attempt is made to maneuver an aircraft which is already

flying at this optimum heading, the miss distance will decrease. In some situations the miss may be decreased to zero by a turn in either direction (see Example 11 of Appendix C). All these statements are demonstrated analytically in Appendix A.

The IPC algorithm does not consider the existence of an optimum heading in deciding to issue commands. As a result, aircraft may be turned when they are already at or near the optimum heading. They may also be turned past the optimum heading and back into conflict (see Examples 12 and 13 of Appendix C). The IPC algorithm does not recognize situations in which a turn in either direction can bring the aircraft to a collision course. If the conflict detection logic requests commands in such a situation, commands will be issued.

It is of course possible, if resolution is begun early and if the slower aircraft maneuvers through a large enough angle, to force the aircraft through the collision geometry before closest approach. In that case the turn only makes the situation worse momentarily before making it better. However, such resolution strategies are risky when the rate and degree of compliance that can be expected from the pilot are uncertain, or when the time available for resolution is short. Furthermore, pilots who visually acquire often interpret commands which oppose the existing miss as evidence that the system has an incorrect perception of the situation.

4.4.2 Rule A Commands Which Oppose Existing Miss

Command selection Rule A turns each aircraft away from the bearing of the other in an attempt to decrease the closure rate to zero. The relative

motion analysis (Appendix A) reveals that this normally means that at least one aircraft is commanded to turn in a direction that decreases miss distance. Negative commands issued under Rule A have the effect of prohibiting one aircraft from turning in the direction which would increase miss distance, but allowing a turn which would eliminate miss distance (see Example 14 in Appendix C).

This strategy is effective in cases in which the closure rate is forced through zero at adequate range. However, if the aircraft does not comply vigorously enough or if the threat develops too rapidly, the closure rate may not be eliminated. The effect of the command may then be that aircraft are placed on collision courses.

4.4.3 Use of Rule A For DOT > 0

Rule A of the IPC horizontal command selection logic (turns each aircraft away from the current location of the other). This rule chooses a direction depending upon whether the threat aircraft is in the right hemisphere (bearings positive 0^{o} to $+180^{o}$), or left hemisphere (bearings negative -180^{o} to 0^{o}). Fig.4-3 illustrates a geometry in which this rule results in questionable commands. Normally Rule A is not applied in this geometry because the logic recognizes this geometrical situation and applies Rule C instead (thus assuring effective right/left commands). However, if the range rate is positive the horizontal command selection logic will force Rule A to be applied. (The range rate can be positive at the time of command generation if aircraft are closing vertically so that vertical tau delays command generation until after horizontal closest approach). Example 15 in Appendix C illustrates this phenomenon.

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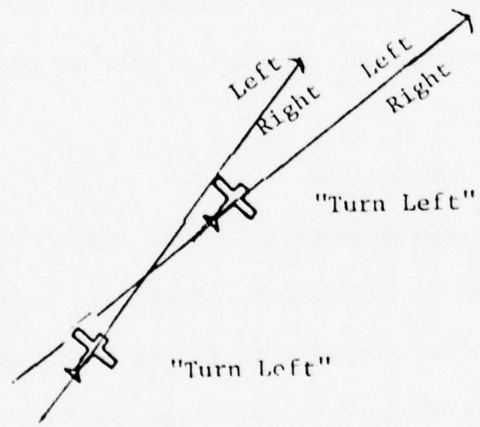

Fig. 4-3. Geometry in which application of Rule A results in ineffective commands.

4.4.4 Course Recovery

The IPC system is designed to assume control only when certain alarm thresholds are violated. When control actions succeed in driving alarm varibles above the critical thresholds, control is dropped and aircraft are free to recover their original courses. Flight test experience has shown that in certain cases this approach leads to incomplete and unacceptable resolution due to the fact the aircraft are unable to safely recover their initial headings after commands are dropped.

An example of this phenomenon is provided in Fig. 4-4. Here resolution was attempted by turning one aircraft away from the other in order to eliminate the closure rate. This turn was successful in its objective and collision avoidance commands were dropped. At this point the pilot who had turned had a PWI indication indicating traffic at his six o'clock position. He turned back to recover his original course* and a second collision hazard arose. Because of the acceleration involved in recovery, the second set of

*Immediate return to course maneuvers are typical of subject pilots (see Section 5).

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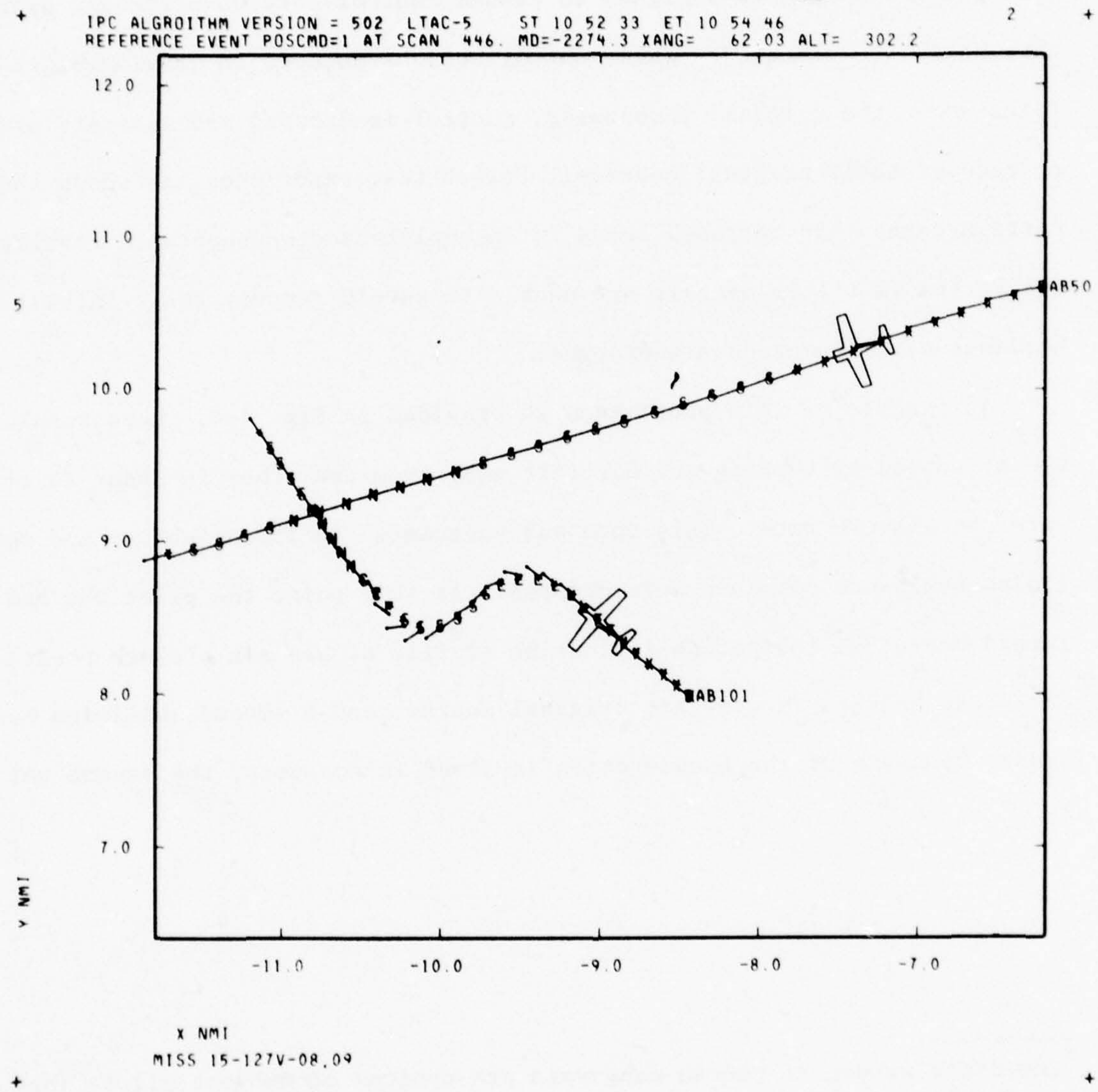

Fig. 4-4. Plot of encounter in which attempt to recover course resulted in second collision threat.

avoidance commands were late and the net effect of intervention by the collision avoidance system was to reduce the miss distance. An analysis of this particular encounter in bearing space (Fig. 4-5) reveals the nature of the general phenomenon. Point A corresponds to the encounter locus just before the maneuver command was effected. Point B corresponds to the locus just after the command was effected. Note that the maneuver has forced the locus across the $\mu=0$ contour and that the direction of natural motion is consequently reversed. The natural motion which takes place at the new heading opposes the miss distance which existed initially. Thus when the aircraft returns to course (C to D) the locus returns to the vicinity of the $\mu=0$ contour.

Such behavior tends to arise when the turn to decrease the closure rate requires crossing the $\mu=0$ contour, i.e., turning through a zero miss distance heading. In such a case the integrated result of maneuvering and returning to course can decrease miss. This difficulty does not arise for maneuvers which maintain the sign of the initial miss distance since any natural motion which occurs will then reinforce the initial miss distance.

Although the example utilized above involves only a single commanded aircraft, a similar phenomenon has been observed when both aircraft are commanded. For equal speed aircraft executing symmetric (mirror image) Rule A turn-away commands, the miss distance which will exist after course recovery will be identical to the miss distance before commands. The symmetry must be broken in order for the aircraft to recover course with a modified miss distance.

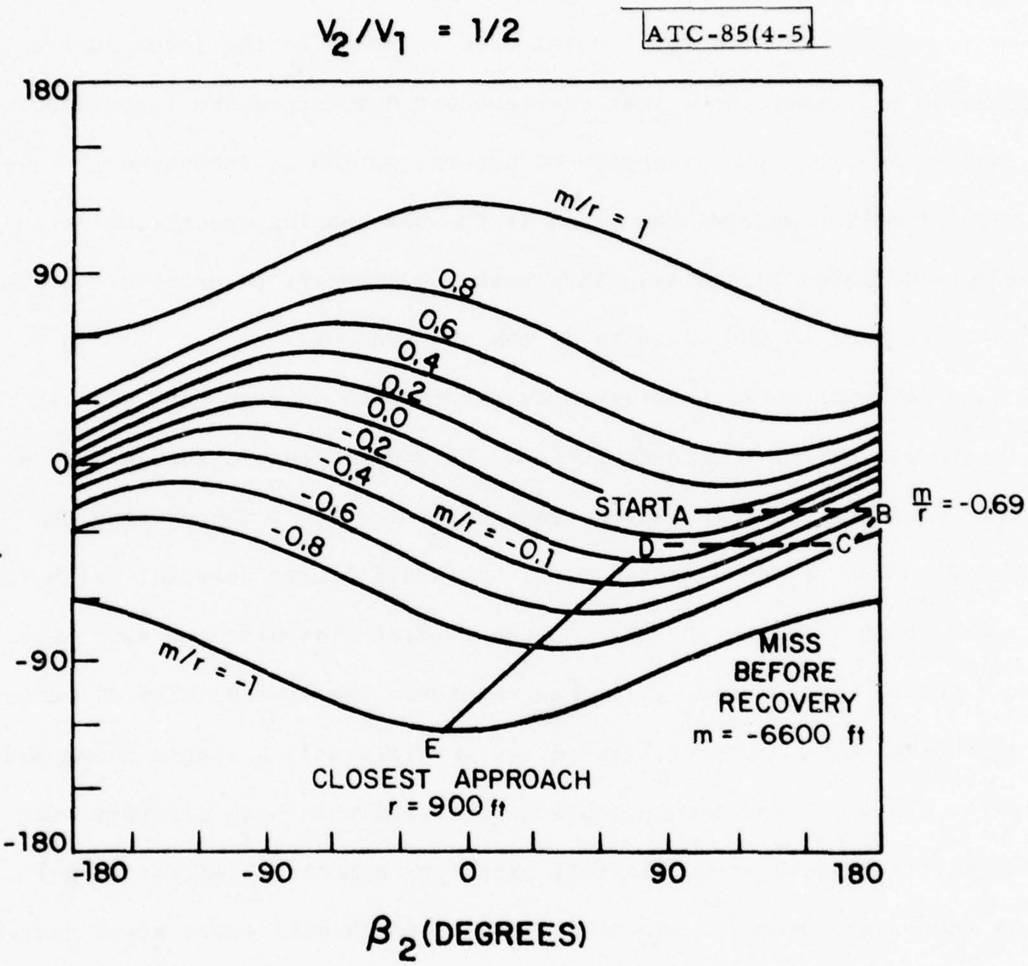

Fig.4-5. State variable plot of recovery encounter of Fig.4-4.

4.5 Resolution of Maneuvering Encounters

Especially severe heading uncertainties can arise when pilots initiate turns prior to the time at which collision avoidance instructions are generated. As was discussed in Section 4.1, the tracker estimate of heading tends to lag behind the actual heading during turns. This tracking lag can readily exceed 40°. An equally significant component of the total uncertainity is the heading change which may take place between the time instructions are generated and the time at which the pilot effects the indicated maneuver. If a turn at a rate of 4°/sec is underway, and if the time required for message transmission and pilot reaction is 10 seconds, then the pilot will turn an additional 40° during the response delay. Thus a total uncertainity of $\pm 80^{\circ}$ may exist. The effect of such uncertainties upon resolution success is discussed below.

4.5.1 Reduced Warning Time Due To Acceleration

When aircraft are turning in directions which increase the closure rate, the estimated value of TH may grossly overestimate the time available before collision. Example 16 of Appendix C illustrates a case in which the tau threshold is 64 seconds, but commands are not transmitted to the aircraft until about 16 seconds before closest approach (the TH estimate decreases from 195 seconds to 50 seconds in one scan). Such encounters may still be resolvable if commands are in the most effective directions (see next paragraph) and if pilots comply with immediate and forceful maneuvers. However, any less favorable conditions can result in resolution failure. It should be

noted that in such accelerating encounters, increasing the value of the TH threshold has little effect upon the time at which commands are issued.

4.5.2 Determination of Command Directions

The impact of large heading uncertainties upon command selection can be understood in bearing space by considering the extent to which the encounter locus is displaced by possible differences between the bearings at which commands are generated and the bearings at which the commands are effected. For example, an encounter which is estimated to be at locus "A" in Fig. 4-6 may actually be at any point within the indicated rectangle by the time commands are effected. If the uncertainties are such that the locus moves from "A" to "B" then commands which were selected to increase the perceived miss distance at "A" (i.e., move the locus toward $\mu = -1$) will actually force the aircraft back toward a collision. Such detrimental commands are quite likely whenever the aircraft are maneuvering from a region in which one set of command directions are appropriate into a region for which the opposite command directions are appropriate.

Examples 17, 18, and 19 of Appendix C illustrate encounters in which IPC commands turned aircraft toward the collision threat. Example 20 is an interesting case in which a negative command was in the wrong direction due to accelerations by one aircraft.

4.5.3 Design Changes Required to Accommodate Accelerating Aircraft

Analysis of resolution failures caused by aircraft acceleration indicates that the capability of IPC to accommodate such situations could be greatly improved by efforts in the following areas:

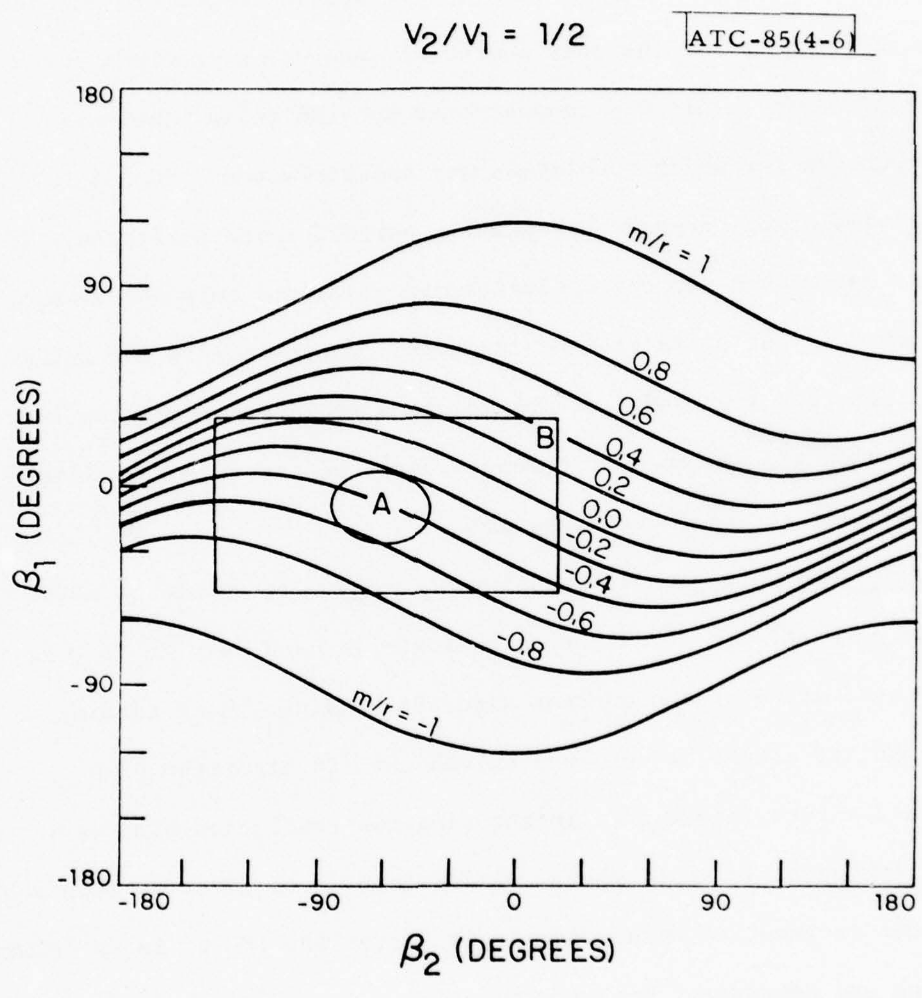

Fig.4-6 Uncertainty in bearing locus due to aircraft accelerations.

a) Tracking. The tracker parameters can be adjusted to better reflect actual surveillance quality. The ability of the tracker to follow turns can be improved by taking aircraft speed and turn detection reliability into account. However, it should be reiterated that tracker lag is not the only source of resolution problems for maneuvering aircraft. This was demonstrated by simulating maneuvering encounters for which resolution was unsatisfactory, but employing for simulation purposes essentially perfect track estimates. In most cases even perfect estimates can eliminate only one scan of alarm delay or a fraction of the total uncertainty in the future trajectory. Improved tracking may be a necessary condition for achieving the desired performance level, but it is not by itself sufficient (see paragraphs below).

b) Use of turn detection in choosing strategy. It should be noted that currently the turn detection logic is used only to improve the estimation of the current aircraft heading. Many turning encounters cannot be resolved unless the IPC algorithm also utilizes turn information in choosing the resolution strategy. For instance, in cases where continuation of an existing turn would result in adequate separation it is better for IPC to issue commands which are consistent with the existing turn rather than to attempt to reverse the turn. In IPC flight tests, it has been observed that

attempts to resolve encounters by reversing existing turns are often ineffective. One reason for this is the fact that the response delay is effectively doubled. For example, if the pilot requires 10 seconds to reverse his turn, an additional 10 seconds is required just to turn back to the heading which existed when commands were received. It is also possible that the existing turn is necessary due to factors of which the IPC system is unaware (e.g., clouds, non-beacon aircraft, etc.). If the existing turn does not assure resolution, then vertical commands should be considered.

c) Improved alarm criteria. The critical IPC alarm variables such as tau and miss distance are calculated under an implicit assumption of rectilinear flight. When headings are changing, the calculated values can vary greatly from scan-to-scan. One cannot protect against this uncertainty merely by increasing the alarm thresholds since the thresholds then required would produce intolerably conservative alarms in many cases. However, the IPC algorithm can be made to use alarm criteria which take potential or detected turns into account in a relatively efficient manner, i.e., which set an alarm flag only when a maneuver would be truly hazardous. The additional alarm thus generated may result in increased issuance of negative commands, but need not cause an increase in the number of positive commands (see item d).

d) Prevention of adverse maneuvers. The IPC system is capable of preventing maneuvers which would create resolution problems. One manner in which this is done is the issuance of PWI warnings to the pilot in order to allow him to acquire his traffic visually. In many cases it can be assumed that PWI-aided visual acquisition will prevent maneuvers which increase the hazard. However, even with PWI adverse maneuvers can still occur under the following conditions:

1. A pilot may initiate a maneuver before PWI alarms appear and continue the maneuver until receiving commands.
2. A pilot receiving a PWI from the six o'clock sector in which his view is obstructed by the airframe may perceive a turn as an acceptable option for a tail chase situation and turn in either direction.
3. A pilot may turn in order to rotate obstructing airframe and acquire the traffic indicated by the PWI.
4. A pilot may initiate a maneuver which he thinks will resolve the conflict and receive IPC commands which reverse his maneuver.
5. A pilot may fail to locate the traffic indicated by the PWI and maneuver anyway on the assumption that if the maneuver is not acceptable, the IPC system will issue further alarms. This reaction is sanctioned by the Pilot's Guide to Intermittent Positive Control (Ref. 6).
6. An ATCRBS aircraft may maneuver toward a DABS aircraft.

Although it is impossible to find a collision avoidance strategy which is always effective in Case 6, the other cases can be solved within the framework of IPC. One approach is to identify those geometries in which maneuvers can produce resolution failure and issue negative commands which instruct the pilot not to maneuver in specified directions. Such commands can prevent a pilot from inadvertently blundering into situations in which IPC offers insufficient protection. This concept is consistent with the description of the negative command philosophy which states that the negative command is issued to the pilot when his current trajectory is satisfactory but a hazard would develop if he were to maneuver (Ref. 1). However, the current algorithm in fact does not consider issuance of negative commands until a hazardous closure rate has already been established.

It has also been observed that such negative commands are generally needed in situations in which their violation is certain to produce positive IPC commands (Ref. 1). Under such conditions negative commands result in no real increase in the restrictions which IPC is imposing upon the pilot -- it is just a question of informing the pilot that he is restricted by nearby traffic rather than allowing him to be surprised by the restriction when he inadvertently precipitates positive commands.

4.6 Three-Dimensional Resolution

The IPC command selection logic attempts to select either horizontal commands which ensure horizontal separation or vertical commands which ensure vertical separation. The command directions which the logic chooses in one

plane are independent of the dynamics of the encounter in the other plane. In many situations this approach is acceptable, but in certain cases failure to consider all three dimensions simultaneously can result in an inability to select proper commands. In particular, whenever vertical rates exist horizontal maneuvers can decrease the vertical component of three-dimensional closest approach. In order to see this, consider a quantity Z_{CA}, defined as the vertical separation which will exist at the time of horizontal closest approach (when $|\mu| = 1$). The actual slant (3D) range at closest approach is then $\sqrt{z_{CA}^2 + m^2}$. For aircraft which are converging in altitude at a constant rate, the altitude difference Z_{CA} is a linear function of the time to closest horizontal approach, t_{CA}. If z_o and $\dot{z}_o$ are the altitude separation and altitude rate at a given time, then

$$z_{CA} = z_o + \dot{z}_o \, t_{CA}$$

Therefore, a contour in bearing space which defines a constant t_{CA} also defines a constant value of Z_{CA}. A set of such contours is provided in Fig. 4-7 for a speed ratio of 1:2. The greater the vertical rate, the greater will be the variation of Z_{CA} with t_{CA}. If there is no vertical velocity, then each t_{CA} contour corresponds to the same Z_{CA} value (i.e., $Z_{CA} = z_o$) and bearing locus has no effect upon the vertical separation.

Possible t_{CA} values (in units of r/V_1) run from $1/(1+\gamma)$ to $1/(1-\gamma)$. When the time to zero altitude separation, $-z_o/\dot{z}_o$, is within this range, a contour

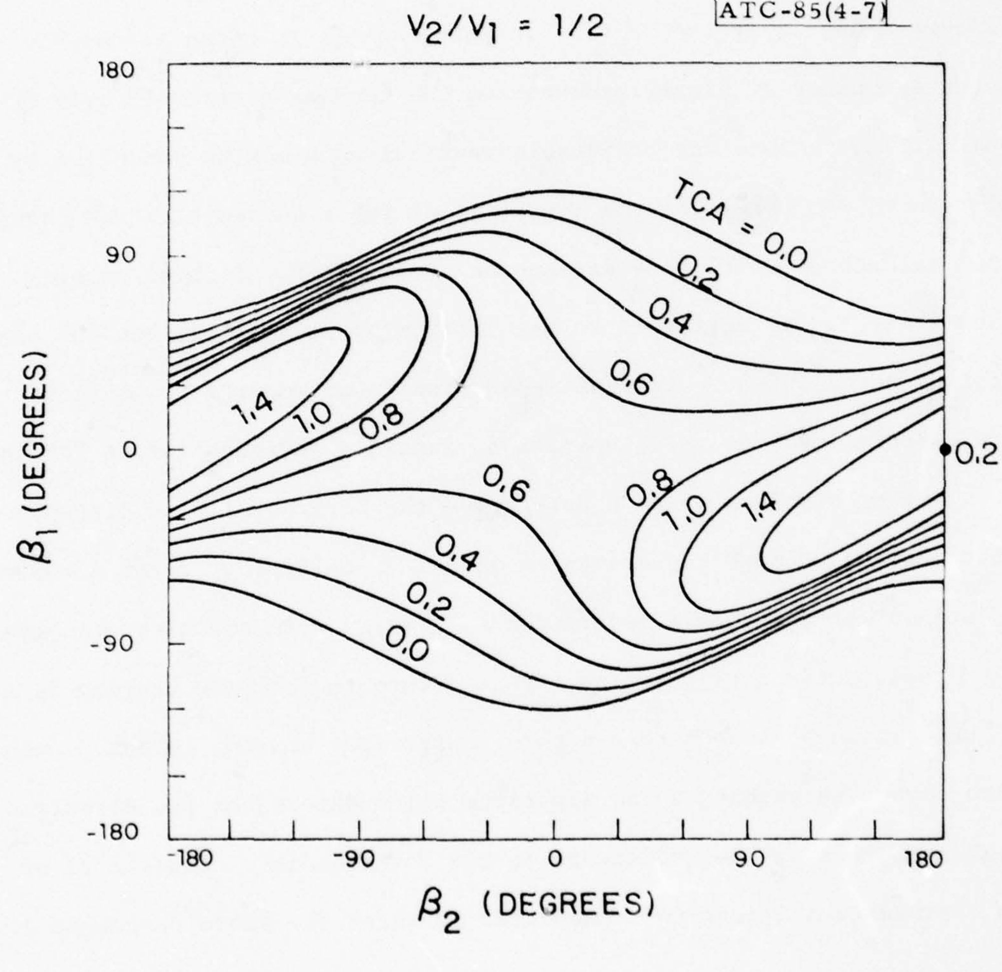

Fig.4-7. Contours of constant time to closest approach (units of r/V_1).

exists for which z_{CA} is zero. If the contour of zero horizontal miss distance ($\mu = 0$) intersects this contour, then the point of intersection is the bearing locus at which a true 3D collision will occur (because for that locus vertical and horizontal separation will reach zero simultaneously).

Three dimensional considerations are especially important when an uncommanded aircraft has a vertical rate. In this case it is often impossible to resolve the encounter by simply maneuvering the commanded aircraft away from the threat altitude since the achievable vertical rate may be cancelled by the vertical rate of the threat, or the magnitude of the required altitude change may exceed allowable limits (see discussion of the vertical chase problem in Section 4.3). It is desirable to use horizontal resolution, but the current IPC algorithm may eliminate vertical separation in attempting to increase horizontal separation. As an illustration, consider an encounter at "X" in Fig. 4-8. Turns to points A and B both drive the horizontal miss distance to zero. But whereas point B represents an actual 3D collision, point A represents a case in which altitude separation will exist when the aircraft pass through the same horizontal position. Thus a turn to decrease bearing is a possible resolution option whereas a turn to increase bearing is not. Such a conclusion cannot be reached by an algorithm which determines the direction of horizontal avoidance without reference to the 3D situation. Example 21 of Appendix C presents a flight test encounter in which the above phenomena is evident.

4.7 IPC Performance in IFR/VFR Encounters

4.7.1 Description of IFR/VFR Logic

When an IFR aircraft is in conflict with a VFR aircraft, IPC attempts to avoid issuance of commands to the IFR aircraft by maneuvering the VFR

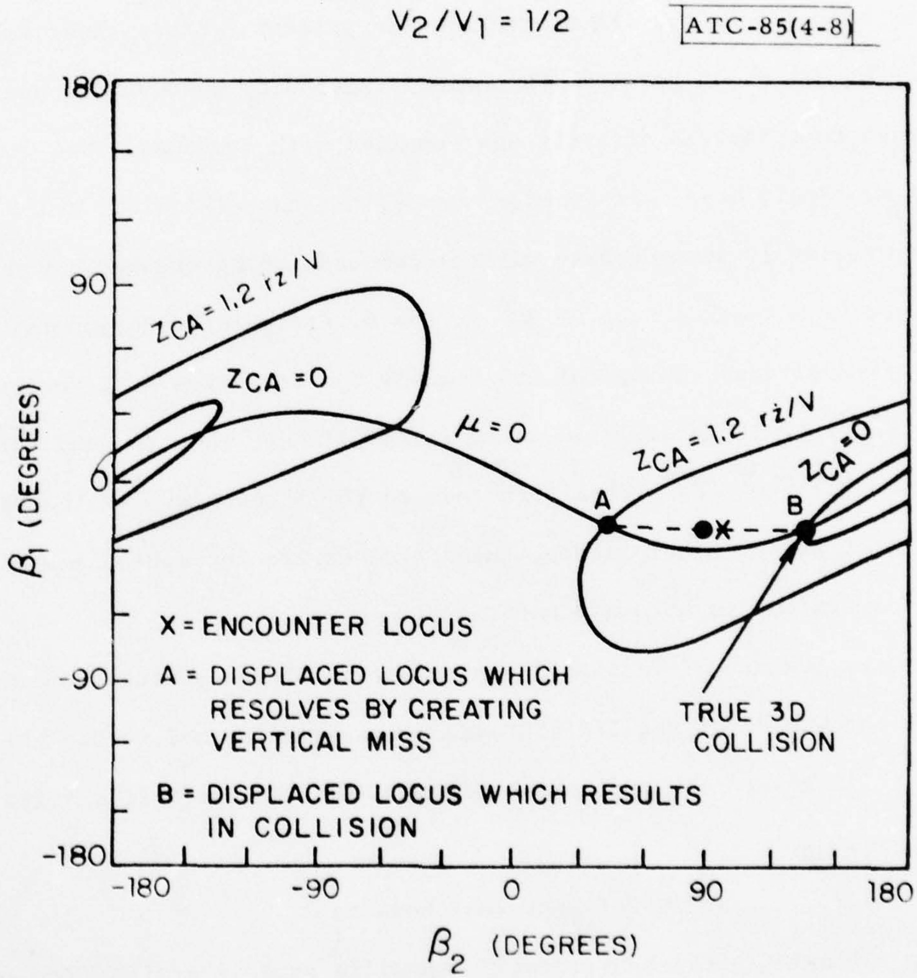

Fig. 4-8. Three dimensional considerations in encounter for which horizontal command affects vertical miss.

aircraft first. In Version 1 this strategy was implemented by using larger tau thresholds for the VFR aircraft. This logic was often successful, but the rate of commands to the IFR aircraft was still unacceptable to the algorithm designers. Consequently in Version 3, logic was added to further suppress commands to the IFR aircraft. The primary feature added was a compliance test which reduces IFR command thresholds whenever it has been determined that the VFR aircraft has complied with commands. The compliance test is made only once. It is made when either tau (TH) drops below 30 seconds or when 27 seconds pass without commands being dropped. Compliance is defined as a tracked turn of 30° in the direction of a horizontal command or a tracked altitude change of 200 feet in the direction of a vertical command. If the VFR aircraft is declared to be in compliance, then the tau threshold for commands to the IFR aircraft is reduced to 15 seconds. If the VFR aircraft is found not to be in compliance, then commands are recomputed and issued in both dimensions to both aircraft.

Another feature of Version 3 was reduction of the positive command miss distance threshold for the IFR/VFR encounters from 1.0 nmi to 0.5 nmi. A test which increased IFR tau thresholds when the VFR aircraft was faster was dropped.

4.7.2 IFR/VFR Flight Test Results

The following paragraphs identify specific aspects of IFR/VFR performance which are relevant to the question of system acceptability.

(a) In the 110 IFR/VFR encounters flown using the full IFR/VFR logic with subject pilots operating the VFR aircraft, commands to the IFR aircraft were averted half the time. The breakdown of IFR encounters was as follows:

No commands to IFR:	55 cases
Negative command to IFR:	18 cases
Single positive command to IFR:	12 cases
Double Positive Command to IFR:	25 cases

(b) The compliance test is ineffective in preventing positive commands to the IFR aircraft. It can succeed only when a very special sequence of events occurs according to the following scenario:

> The VFR aircraft acknowledges and maneuvers in compliance with his IPC command, but either tau drops below 30 seconds or commands persist for 27 seconds. A test for compliance is made. The VFR aircraft is found to be in compliance, and commands are not issued to the IFR aircraft. The encounter is finally resolved without tau going below 15 seconds.

In flight tests this scenario was practically never realized for the following reasons:

1. When the VFR aircraft maneuvers promptly, tau may never go below 30 seconds and the compliance test may never be exercised.
2. Due to the tracker lag, the VFR aircraft is often declared not to be in compliance even when he is responding; then the compliance check results in commands.
3. When tau goes below 30 seconds it often also goes below 15 seconds and commands are issued in spite of the compliance test.

4. When the VFR heading changes, horizontal miss distance tends to increase above the 3000 foot threshold and positive commands are replaced by negative commands.

5. The system may declare the VFR aircraft non-complying without allowing sufficient time for compliance (see following paragraphs).

6. If the VFR pilot fails to acknowledge commands within 8 seconds, commands are sent immediately to the IFR aircraft.

(c) The fact that the VFR aircraft has turned 30^{o} or climbed 200 feet does not necessarily mean that the collision hazard has diminished. Appendix A discusses situations in which a slower aircraft can turn 90^{o} or more and still be on a collision course. In the vertical plane a 200 foot altitude change by the VFR aircraft is also of questionable value since the altitude reports themselves are quantized in 100 feet increments. Altimeter errors and normal altitude variations by the IFR aircraft can quickly erase the separation generated by such compliance.

(d) The 15 second tau threshold is inadequate to assure resolution when a maneuver by the IFR aircraft is required to avoid collision. The 4-second scan period of the DABS system can result in commands being delivered almost 8 seconds after tau decreases to 15 seconds. Although horizontal tau is modified so that time-to-collision is greater than the actual tau value, the extra lead time provided in higher closure rate situations is not significant. Furthermore, vertical tau is not modified. Thus if the closure rate is high or if aircraft are closing vertically, commands may reach the IFR pilot only a few seconds before collision.

(e) The recomputation which is called for when the VFR aircraft is declared to be non-complying often reverses the direction of turn commands. See Section 4.8 for discussions of the detrimental effects of such reversals.

(f) The strategy of issuing commands to the VFR aircraft without issuing commands (or in some cases traffic advisories) to the IFR aircraft does not assure safety. Minor course changes by the uniformed IFR aircraft may cancel the effect of the VFR aircraft's maneuver. This is especially true when the IFR aircraft is faster. The philosophy of allowing IFR aircraft to approach very close to VFR traffic while receiving no information other than PWI's should be re-examined. Examples 22 and 23 of Appendix C illustrate cases in which no IPC messages were sent to the IFR aircraft until after the IFR pilot had initiated hazardous turns.

(g) Change M-15 of Version 4 was introduced in order to reduce the frequency of commands to IFR aircraft when IFR and VFR aircraft are flying with approximately 500 feet of altitude separation (a separation often resulting from the cruise altitude recommendations of FAR 91.109 and 91.121). The IFR aircraft will not receive positive commands unless TH is less than 30 seconds or the altitude separation is less than 370 feet. When the VFR aircraft is ATCRBS this logic makes resolution success highly dependent upon whether or not the ATCRBS aircraft holds its altitude. If the ATCRBS aircraft begins to climb or descend toward the IFR aircraft, then vertical tracker lag can result in positive commands being issued to the IFR at a time too late to be effective (see Example 24 of Appendix C).

(h) In encounters between VFR ATCRBS aircraft and IFR DABS aircraft, commands are selected for the pair when the VFR command thresholds are violated.

The command to the ATCRBS aircraft cannot be delivered, but is stored in the pair record nevertheless. The command to the IFR is also stored and is issued if and when the IFR command thresholds are violated. This may occur many scans after the command was first generated. Since the motion of neither aircraft was constrained by commands during the storage interval, the collision geometry may have changed considerably by the time the command is issued. In these cases the command may be "obsolete" and not effective in resolving the encounter. Example 24 of Appendix C illustrates this phenomenon.

(i) Commands in both the horizontal and vertical planes are routinely issued when VFR DABS aircraft are declared to be non-complying. But there is no provision for issuing commands in more than one plane to IFR DABS aircraft in conflict with VFR ATCRBS aircraft. Vertical chase problems can result (see Example 24 of Appendix C).

(j) If the compliance test fails, commands in both dimensions are transmitted to the IFR aircraft. These dual dimension commands are more disruptive to flight objectives than a single dimension command would be.

(k) Often commands to the IFR aircraft are preceded by only a single scan of flashing PWI or by ordinary PWI rather than flashing. The IFR pilot is then unprepared for prompt compliance.

(l) In some cases the VFR aircraft receives a climb/descend command before the IFR aircraft receives any PWI or command. If the IFR aircraft then initiates an altitude rate toward the VFR aircraft, it is possible for the IFR aircraft to remain close enough to continue the command to the VFR but at a separation which precludes any command being issued to itself. The VFR aircraft can be forced to make excessive altitude changes (see Example 8 of Appendix C).

(m) The complying VFR aircraft can be forced to make excessive magnitude turns in order to avoid an uncommanded IFR aircraft. This is especially true in dynamic situations for which the horizontal maneuver options of a slower VFR aircraft are ineffective (see Section 4.4.1).

(n) VFR subject pilots tended to resist large magnitude turns when they had visually acquired their traffic. This tendency could lead to double commands being issued to IFR aircraft in a large number of IFR/VFR encounters (see Section 4.4.1 for further discussion).

(o) If negative commands are issued initially then positive commands are delayed even though tau is decreasing. If a negative-to-positive transition then occurs, the compliance test may be applied immediately due to the 30 second tau test. As a result IFR and VFR aircraft may receive initial commands simultaneously even though both aircraft were complying with IPC instructions (see example 25 of Appendix D).

4.8 Other Logic Validation Results

4.8.1 Vertical Commands Near Altitude Crossover

Special difficulties were observed in selecting the direction of vertical commands for aircraft which possess a significant vertical closure rate and are within a few seconds of crossing in altitude. In such cases the aircraft could cross in altitude before the commands could be effected. The commands were then in directions which forced the aircraft back toward each other. Version 3 added logic which reverses the direction of positive commands whenever vertical tau (TV) is less than TV1 (8 seconds) at the time commands are generated. This is intended to result in commands which reinforce the altitude separation

which will exist by the time the pilots begin responding to commands. When TV is between TV1 (8 seconds) and TV2 (16 seconds) horizontal commands are chosen because of the difficulty in choosing suitable vertical command directions. Although this change is an improvement over the previous logic, it does not eliminate all difficulties. The uncertainties in the TV estimate and in pilot response times are large compared to the TV thresholds which must be employed. In some cases pilots who acquire visually shortly before commands are issued act quickly to halt their climb/descent. But the IPC algorithm, with estimated vertical velocity lagging behind the actual velocity, may perceive an imminent altitude cross-over and issue reversed commands. The aircraft are then commanded to maneuver into each other. Furthermore, late pilot response or overestimation of TV can still lead to crossover which invalidates the command directions. Fortunately, in these cases there is normally sufficient time to overcome the effect of the uncertain altitude dynamics and achieve vertical separation with the generated commands. It is easier to assure that this time exists than to attempt to define logic which can function in the face of such uncertainties.

4.8.2 Positive/Negative Transition Logic

The IPC master resolution module contains logic which is intended to change negative commands to positive commands and vice-versa as required. The Version 1 logic did not properly transition when positive commands existed in both maneuver planes. In this case the horizontal command could be transitioned from positive to negative leaving a superfluous positive vertical command on the display. Change M16 of Version 4 was intended to revise the

logic to eliminate this problem. However, as currently defined the logic is unsuitable for use in multiple encounters since it allows critical commands to one aircraft to be deleted due to positive/negative transitions undergone with respect to a second aircraft. For this reason the change was never fully implemented in the test bed version of the algorithm.

When commands have been issued in one plane, no test is made later to determine the type of commands which would suffice in the other plane. The question may arise as to whether a negative command in the alternate plane can replace a positive command in the original command plane. In some cases, as was pointed out in Section 4.3(a), a negative command in the original plane transitions to a positive command even though a negative command in the alternate plane would suffice. It is also possible for a positive command to continue for many scans when a negative command in the alternate plane would be adequate (Example 26 of Appendix C).

4.8.3 Command Reversals

The IPC algorithm may recompute the direction of horizontal commands during an encounter. Such recomputation occurs (1) when a positive/negative command transition takes place, (2) when a VFR DABS aircraft is declared non-complying by the IFR/VFR compliance logic, or (3) under certain conditions when positive commands have been present for 27 seconds and miss distance (MD) is decreasing. If the recomputed command is in a different direction than

the original command, a pilot will be instructed to reverse the direction of his maneuver. Several pilot reaction problems associated with command reversals are discussed in Section 5.5. Algorithmic considerations are discussed below.

Reversal of command directions is justified in cases in which the geometry of the conflict has changed in a manner that makes the original commands ineffective. But the IPC logic bases the decision to reverse upon criteria which are only indirectly related to whether or not a reversal is truly necessary. In some cases commands are reversed after having been displayed for only a single scan (see Example 38 of Appendix C). Reversals can occur because of small changes in the geometry which produce a crossing of a decision boundary in the command selection logic (e.g., when crossing angle changes from 89.9° to 90.1° and the logic switches from Rule A to Rule B). Flight test experience indicates that the tracking lag and pilot response delays are large enough to make reliable command reversal impossible in the time frame in which IPC works. In Section 4.5 it was pointed out that when aircraft are turning, the difference between current estimated heading and the heading at which commands are effected can be very large. If a turn has begun due to the initial command, then reversal of the turn will lead to all the difficulties inherent in command selection for maneuvering aircraft. In the worst case, aircraft can be commanded to zig-zag back and forth across their original flight paths and the effect of commands upon miss distance may integrate to zero (see Example 27 of Appendix C). In order to avoid such inappropriate reversals, the IPC logic must be capable of evaluating the effectiveness of existing or proposed commands by examining the actual dynamics of the encounter.

4.8.4 Pair Logic When Only One Aircraft is Uncommanded

The IPC concept states that the algorithm will choose commands which provide maximum separation regardless of whether one or both aircraft maneuver. This is physically impossible in most cases. Certainly when one aircraft is unequipped the command selection should be dependent upon which aircraft will receive commands. But the IPC command selection logic selects command directions without regard to whether one aircraft of the pair is uncommanded. This strategy is especially unsound in situations in which only one aircraft of a pair has an effective horizontal maneuver option (see 4.4.1). For instance, when Rule C is applied the aircraft which is further from path crossing is normally the only aircraft of the pair which can effectively maneuver. In these cases the command selection logic may assign the effective maneuver to the uncommanded aircraft and issue the ineffective maneuver to the commanded aircraft (see Example 10 of Appendix D).

4.8.5 Multiple Aircraft Encounters

Even though the testing of multiple aircraft encounters was not an objective of the IPC flight tests, a number of such encounters occurred inadvertently due to the proximity of itinerant ATCRBS aircraft to the two DABS aircraft conducting intercepts. The details of IPC performance in these encounters will not be reported here since it was acknowledged that the multiple aircraft logic as it now exists is in need of significant revision. But it has become evident that several aspects of IPC behavior in pair encounters are relevant to the success the system may expect in the resolution of multiple encounters.

a) The IPC multiple aircraft logic is based upon the concept of issuing commands in one dimension to avoid the first threat and using a second dimension to avoid the second threat. But if an aircraft has commands in two dimensions due to a single threat, no options remain for avoidance of additional threats. In IPC subject pilot flight tests, the algorithm issued commands in two dimensions in approximately one-fourth of the encounters.

b) The pairwise structure of the IPC logic makes it impossible to establish a preference for commands which will avoid two aircraft at once. There is no safeguard against selecting a command with respect to one threat which makes a second threat worse.

c) If an aircraft maneuvers more than is necessary to avoid one threat his maneuver may carry him into hazard with respect to a second threat. Because IPC tends to overcontrol aircraft and has little control over the final heading, it is difficult to avoid such situations. When an aircraft is commanded to turn, a large uncertainty is introduced concerning the volume of airspace into which it will pass. The larger this uncertainty is, the more difficult multiple resolution will be.

d) Commands which prolong the encounter without resolving it (see Section 4.4.2) increase the likelihood of multiple aircraft encounters.

e) The IPC logic enforces a symmetry of commands which requires commands for both aircraft of a pair and requires commands in the same plane for each pair. This eliminates certain options for multiple aircraft resolution.

4.9 Summary of Algorithm Validation Results

The IPC logic resulting from the flight test program is highly reliable in its ability to track aircraft and identify potential collision hazards. The IPC algorithm demonstrated an ability to generate commands which could resolve many encounter situations in an effective and acceptable manner. However, performance was unacceptable for encounters with certain characteristics. It is helpful to define two categories of encounter characteristics: nominal and non-nominal (see Table 4.1). The IPC logic performance was generally adequate for the resolution of nominal encounters (see Table 4.2) although recovery encounters could arise even there. For encounters possessing non-nominal characteristics IPC performance was often unacceptable. Of particular concern were situations in which commands had a detrimental effect upon aircraft separation.

TABLE 4-1

ENCOUNTER CHARACTERISTICS

Nominal Encounter	Non-Nominal Encounter
No acceleration	aircraft accelerating
and	or
both IPC controlled*	one not IPC controlled*
and	or
similar speeds	dissimilar speeds
and	or
two aircraft only	multiple aircraft
and	or
nominal surveillance	degraded surveillance

*In this context an aircraft is not IPC controlled if it is either not IPC-equipped, uncommanded, or non-complying.

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MAR 78 J W ANDREWS, J C KOEGLER, K D SENNE F19628-78-C-0002
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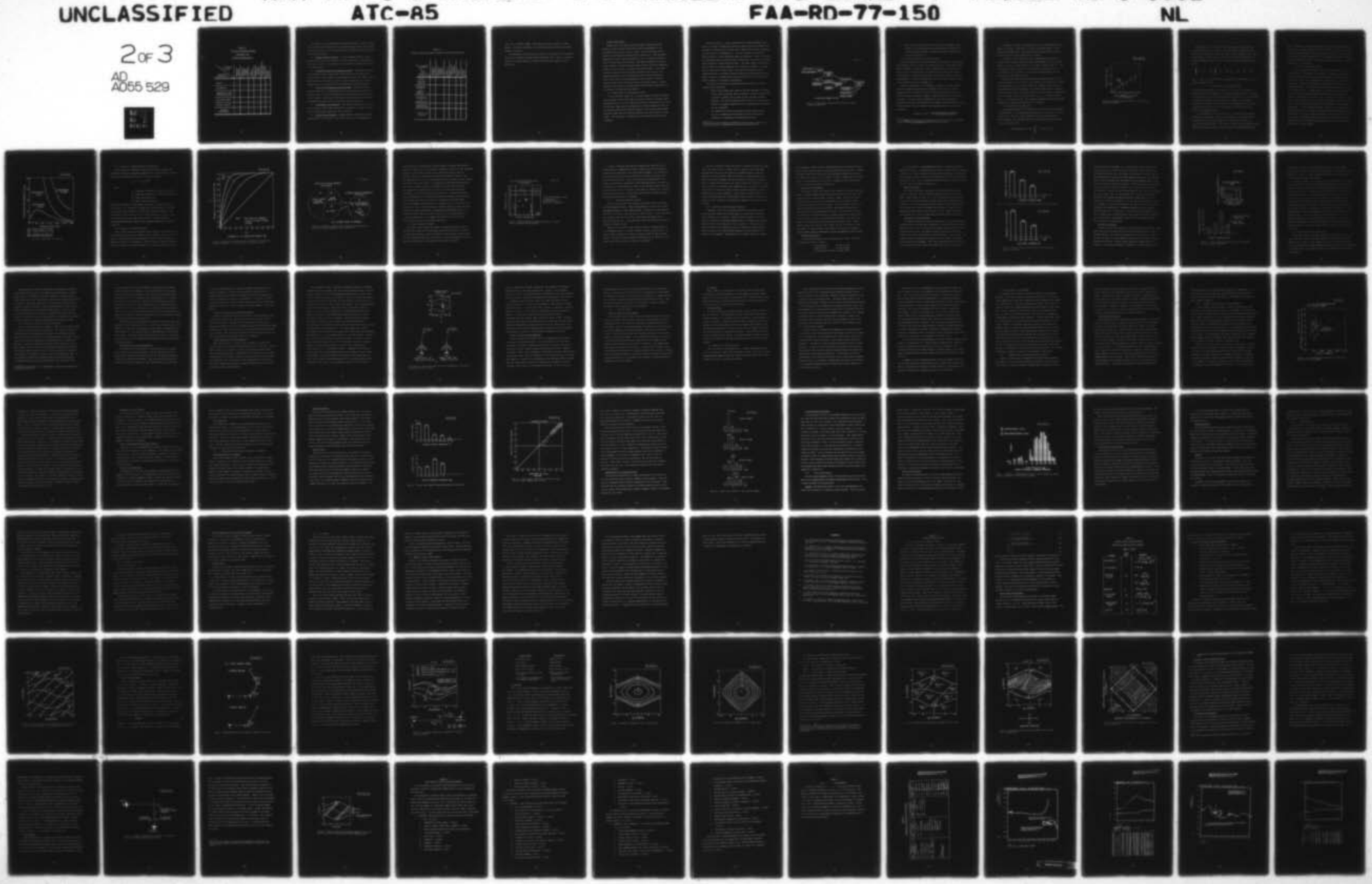

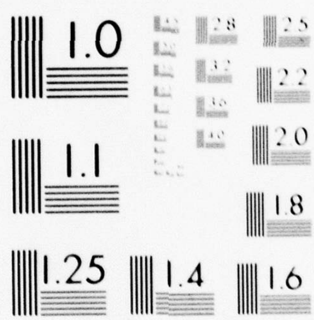
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TABLE 4-2

OBSERVED PERFORMANCE PROBLEMS

CORRELATED WITH

ENCOUNTER CHARACTERISTICS

ENCOUNTER CHARACTERISTIC \ PERFORMANCE PROBLEM	UNNECESSARY COMMANDS	UNSTABLE OR IRRATIONAL COMMAND SEQUENCES	LATE DETECTION	COMMANDS WHICH DECREASE SEPARATION	EXCESSIVE MANEUVER MAGNITUDES	RECOVERY HAZARDS
NOMINAL	✓					✓
ACCELERATING		✓	✓	✓		
UNCOMMANDED OR NON-COMPLYING AIRCRAFT				✓	✓	✓
DISSIMILAR SPEEDS				✓	✓	✓
MULTIPLE AIRCRAFT		✓		✓		
DEGRADED SURVEILLANCE	✓	✓	✓	✓		

An attempt to relate the observed performance problems to certain features of the IPC algorithm design (Table 4.3) provides insight into the shortcomings of the current logic. The following feature of the design are most significant in limiting performance:

a) Delayed resolution strategy. Delaying commands until the latest possible time at which safe resolution is conceivable makes it impossible for the system to recover if some element of the resolution scenario does not turn out as anticipated.

b) Incomplete evaluation of encounter dynamics. The available tracking data concerning aircraft trajectories is not utilized to full advantage in deciding when to issue commands or what commands to issue. The command issuance logic which treats horizontal and vertical planes separately fails to issue commands which are consistent with three-dimensional encounter situations.

c) No explicit consideration of uncertainties. Possible errors in available track data or computed quantities are not explicitly considered in making decisions. Because the magnitude of expected errors often varies with range or geometry, fixed decision thresholds are inefficient. Errors induced by unconstrained accelerations can preclude effective resolution.

d) Indeterminate turn magnitude. Once maneuvers begin, the IPC system has no effective control over the heading of the aircraft. Aircraft can turn past an optimal escape heading back into a collision.

e) Pairwise logic structure. Commands which are reasonable when both maneuver may not be reasonable if only one aircraft is to be commanded (e.g.,

TABLE 4.3

OBSERVED PERFORMANCE PROBLEMS CORRELATED WITH DESIGN ATTRIBUTES

PERFORMANCE PROBLEM / IPC DESIGN ATTRIBUTE	UNNECESSARY COMMANDS	UNSTABLE OR IRRATIONAL COMMAND SEQUENCES	LATE DETECTION	COMMANDS WHICH DECREASE SEPARATION	EXCESSIVE TURNS	RECOVERY HAZARDS
DELAYED RESOLUTION STRATEGY			✓	✓	✓	✓
INCOMPLETE EVALUATION OF ENCOUNTER DYNAMICS	✓		✓	✓		✓
NO EXPLICIT CONSIDERATION OF UNCERTAINTIES	✓	✓	✓	✓		
INDETERMINATE TURN MAGNITUDE		✓		✓	✓	
PAIRWISE LOGIC STRUCTURE	✓			✓	✓	✓

IFR vs VFR, or ATCRBS vs DABS). Many times both aircraft cannot be treated equally. In multiple encounters, the second threat must influence the command chosen for the first.

The performance problems which are related to the design features mentioned above can be eliminated by improving the algorithmic logic. Specific acommendations for such improvements are included in the Executive Summary preceding this report.

5. SUBJECT PILOT RESULTS

Testing of IPC with subject pilots was used to evaluate both the ability of pilots to utilize IPC services and the acceptability of IPC performance from the pilot's point of view. The test procedures used in subject pilot testing have been described in Section 3.2. These procedures attempted to create a flight environment as close to normal as possible in order to obtain valid pilot reactions. The subjects themselves cooperated in this endeavor by maintaining their normal flight practices and suggesting changes in test procedures if something abnormal was noted. A surprising variation in pilot reactions was noted according to pilot behavior and encounter situation. Often considerable review of data was required in order to sort out the various components of pilot behavior. Although eccentric cases can be found which violate any specific pattern, a general picture of pilot reaction has emerged which has far-reaching implications in the design of collision avoidance systems.

5.1 Visual Acquisition Performance with PWI

The role which PWI assumes in a collision avoidance concept is dependent upon the extent to which PWI enhances the pilot's ability to visually acquire approaching traffic. The IPC flight tests provided a substantial body of data in this area. Many previous investigations of visual acquisition either did not involve subject pilots using PWI displays or were conducted with ground simulators which could only partially duplicate the visual factors of actual flight. For this reason, a careful look at the relevant IPC test data is worthwhile.

Direct presentation of test acquisition data is often misleading since the data is highly dependent upon encounter attributes which vary greatly from encounter to encounter such as closure rate, target size, direction of approach, type and timing of PWI warnings, etc. In order to properly interpret PWI flight test data, a visual acquisition model was developed. Figure 5-1 portrays the relationship between the factors which characterize a given search situation and the quantities derived within the model. This model permits data gathered under a variety of approach conditions to be analyzed as examples of a common process rather than as unique events. This section discusses the visual acquisition model to the extent required to explain the data presented in this report. Reference 9 contains a more complete description of the model and its use for prediction of acquisition performance*.

It should be noted that the following limitations apply to the visual acquisition data presented:

a) Subject pilot flights were conducted only when atmospheric visibility of three miles or greater could be obtained. The data collected thus represents a sampling over all days on which such VFR conditions prevailed. The visual acquisition model can be used to predict performance for degraded visibility, but no validating data is available for such conditions.

b) IPC commands were often received before visual acquisition had occurred. Commands may have somewhat affected the subsequent probability of acquisition (by distracting the pilot).

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*The preliminary data analysis in Reference 9 is based upon a partial set of flight test data and is superceded by the analysis presented here.

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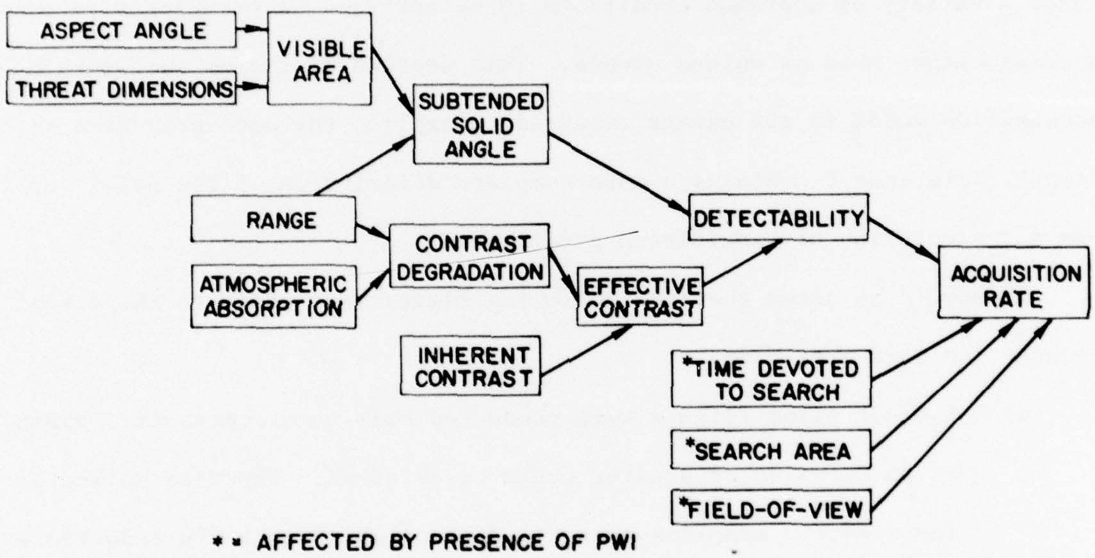

Fig. 5-1. Relationship between factors utilized in visual acquisition modeling.

c) Visual acquisition is merely the first stage in successful visual avoidance. The pilot must also correctly evaluate the threat and execute avoidance maneuvers. Further discussions of this point can be found in Section 5.2.2.

5.1.1 Visual Acquisition as a Poisson Process

The basic mathematical innovation utilized in the model is to characterize the acquisition process in terms of an acquisition rate, λ, which varies with search conditions. Acquisition is then a nonhomogenous Poisson process* for which a count of 0 indicates that no acquisition has occurred and a count of 1 indicates that acquisition has occurred. One may then proceed to determine the dependence of λ upon the variable factors and to compute cumulative acquisition probabilities from a knowledge of λ.

Since the acquisition rate is obviously a function of target proximity, the first dependence examined was the dependence upon range. The range dependence of the acquisition rate can be extracted from the available data in the following non-parametric manner: divide the range axis into intervals of width Δr. For each interval determine the total time during which an undetected target was in the interval and the number of detections which occurred in the interval. Then the estimate of the acquisition rate for the interval is given by

$$\text{acquisition rate} = \frac{\text{total no. detections in interval}}{\text{total time in interval}}$$

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*For a homogeneous Poisson process, the arrival rate is assumed to be constant in time. For the non-homogeneous Poisson the rate may vary.

This analysis revealed a strong tendency for λ to vary inversely as the square of the range. Furthermore, the coefficient which relates λ to $1/r^2$ increased with target size. This suggested that the acquisition rate may be related to the solid angle subtended by the target.

A technique for calculating solid angle subtended by the target was devised and the dependence upon solid angle was determined using solid angle intervals in place of range intervals. The result is shown in Fig. 5-2. This data supports a model for which λ is proportional to solid angle, i.e., $\lambda = \beta A/r^2$ where β is a constant, A is the visible area presented by the target, and r is range between aircraft.

Variations in acquisition performance with and without PWI may be represented by variations in the value of the constant of proportionality, β. Values of β appropriate for each search condition were computed from the test data using maximum likelihood techniques. The results indicate that (for targets within the pilots field of view) the acquisition rate with PWI was approximately six times greater than the rate without PWI, i.e., $\beta = 1 \times 10^4$/sec without PWI, $\beta = 6 \times 10^4$/sec with PWI. The following paragraphs show how these results translate into cumulative probabilities of acquisition.

5.1.2 Acquisition Time Constants

The cumulative probability of acquisition is a function of the integrated acquisition rate. For a given approach trajectory we can express λ as a function of time. Then for a search beginning at time t_0 before collision, the probability of no acquisition when the time-to-collision has decreased to t_1 can be shown to be

$$P[\text{no acquisition}] = \exp \left[\int_{t_0}^{t_1} \lambda(t)\, dt \right], \quad t_0 > t_1$$

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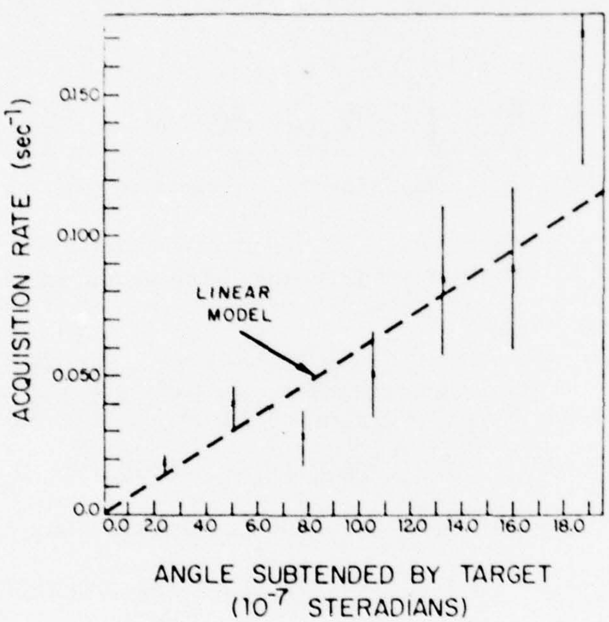

Fig. 5-2. Acquisition rate as a function of solid angle subtended by target.

When aircraft are on co-altitude zero miss distance courses the range rate and visible area are constant. If we ignore any search which may have occurred before the PWI alert appeared, then β is also constant at the β value corresponding to alerted search. Under these conditions the expression for cumulative probability may be greatly simplified. Then the integral defined above is

$$\int_{t_0}^{t_1} \lambda(t)\, dt = \frac{\beta A}{\dot{r}^2} \int_{t_0}^{t_1} \frac{dt}{t^2} = \frac{\beta A}{\dot{r}^2} \left[\frac{1}{t_0} - \frac{1}{t_1}\right] = \frac{T_a}{t_0} - \frac{T_a}{t_1}$$

where $T_a = \frac{\beta A}{\dot{r}^2}$ is an acquisition time constant which is characteristic of the approach conditions. Thus

$$P[\text{no acquisition}] = \exp\left[\frac{T_a}{t_0}\right] \exp\left[\frac{-T_a}{t_1}\right]$$

If the pilot began searching at infinity ($t_0 = \infty$), then T_a is the time-to-collision at which the probability of no acquisition has fallen to e^{-1} (36.8%). The factor $\exp\,[T_a/t_0]$ is the factor by which the probability of no acquisition is increased by failure to begin searching at infinity. If both pilots involved in an encounter are searching, then the probability of neither pilot acquiring is characterized by a T_a value which is just the sum of the T_a values of the individual pilots.

It is convenient to define a value for T_a for which visual acquisition performance is acceptable. One way of doing this is to note that in order to have 98% chance of having acquired by 20 seconds before collision, T_a must be 80 seconds or greater. The value of T_a which will be achieved in actual encounters depends upon aircraft sizes, airspeeds, and approach geometries.

Fig. 5.3 provides T_a values for some specific cases of unobstructed search. Note that for encounters between two type 1 aircraft, T_a is favorable except for higher crossing angles. For type 1 searching for type 2, the larger size of the target more than compensates for its increased closure rate. However, for type 2 searching for type 1, the increased closure rate lowers T_a to values unfavorable for acquisition.

5.1.3 Field of View Considerations

A further consideration arises from the fact that the pilot's view in some directions is obstructed by the airframe. Encounters in which the view of the pilots of both aircraft is obstructed are rare, but encounters in which one pilot's view is obstructed are commonplace. For example in "tail chase" encounters the overtaking aircraft generally approaches from an obstructed bearing. A threat may also approach from head-on below the nose or from behind a wing. In flight tests it was found that pilots who received alerts in obstructed sectors sometimes changed their position within the cockpit or maneuvered the aircraft in order to remove the obstruction. This could result in acquisition of an aircraft which normally would not have been seen. But more typically an approach from an obstructed sector precluded acquisition. It can be inferred from Fig. 5.3 that for slow overtake tail chase situations, the slow closure rate insures that the overtaking pilot will acquire even if the pilot in the lead cannot. But in the case of the large fast aircraft overtaking the small slow aircraft, the closure rate can be substantial and the only pilot with an unobstructed view is the pilot who must search for a small target.

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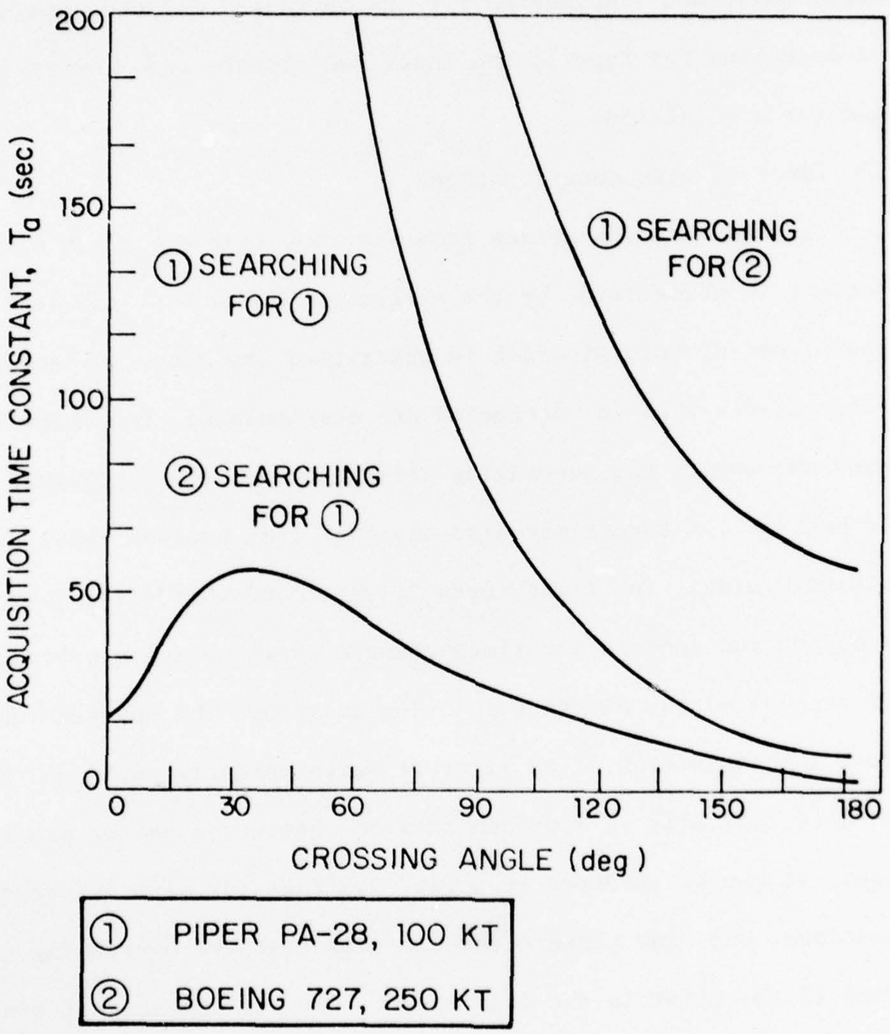

Fig.5-3. Acquisition time constants.

5.1.4 Acquisition Probability With and Without PWI

Under the approach conditions defined in the previous paragraph, the relationship between the cumulative probabilities of acquisition with and without PWI can be expressed in terms of the β ratio as follows:

$$P_1 = 1 - (1 - P_0)^{\beta_1/\beta_0}$$

where

P_1 = cumulative probability of acquisition with PWI

P_0 = cumulative probability of acquisition without PWI

β_1 = model constant with PWI

β_0 = model constant without PWI

Because this expression is independent of the time-to-collision at which P_0 is specified, it is convenient to consider P_0 as corresponding to the latest time at which visual acquisition is effective in allowing avoidance. This relationship is plotted in Fig. 5-4. It can be seen that for $\beta_1/\beta_0 = 6$ (the ratio observed in the IPC flight tests), there is a high probability of acquiring with PWI whenever there is even a modest probability of acquiring without PWI.

5.1.5 Analysis of Acquisition Failures

Visual acquisition data is available for 272 subject pilot encounters. No visual acquisition occurred in 75 (28%) of these encounters (see Fig. 5-5). Furthermore, visual acquisition occurred within 3 scans of closest approach in an additional 56 (21%) of the encounters. These 131 cases of apparent acquisition failure were subjected to further analysis. In 76 of these cases the point of

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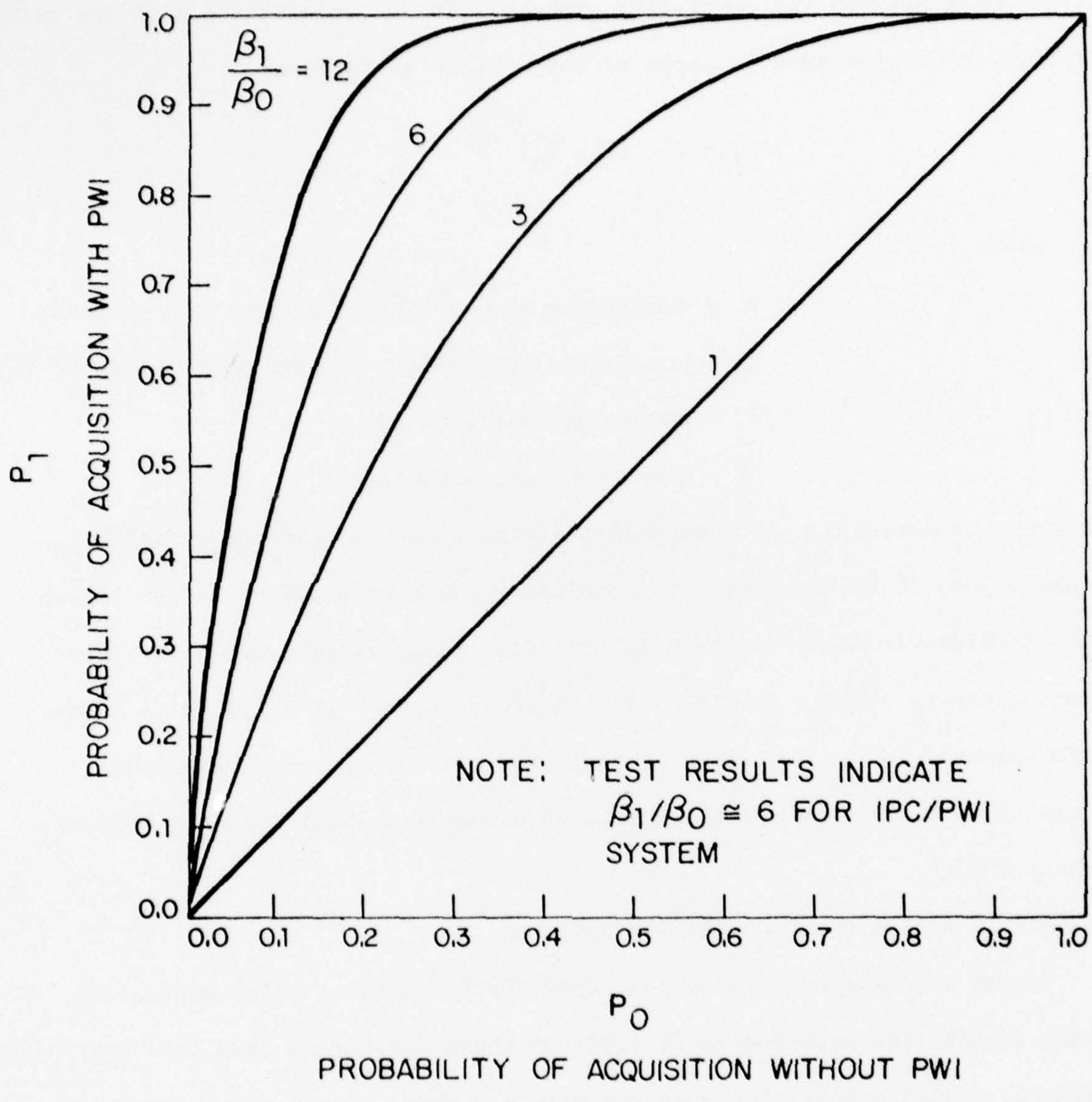

Fig. 5-4. Predicted relationship between probability of acquisition with and without PWI for various ratios of acquisition rates.

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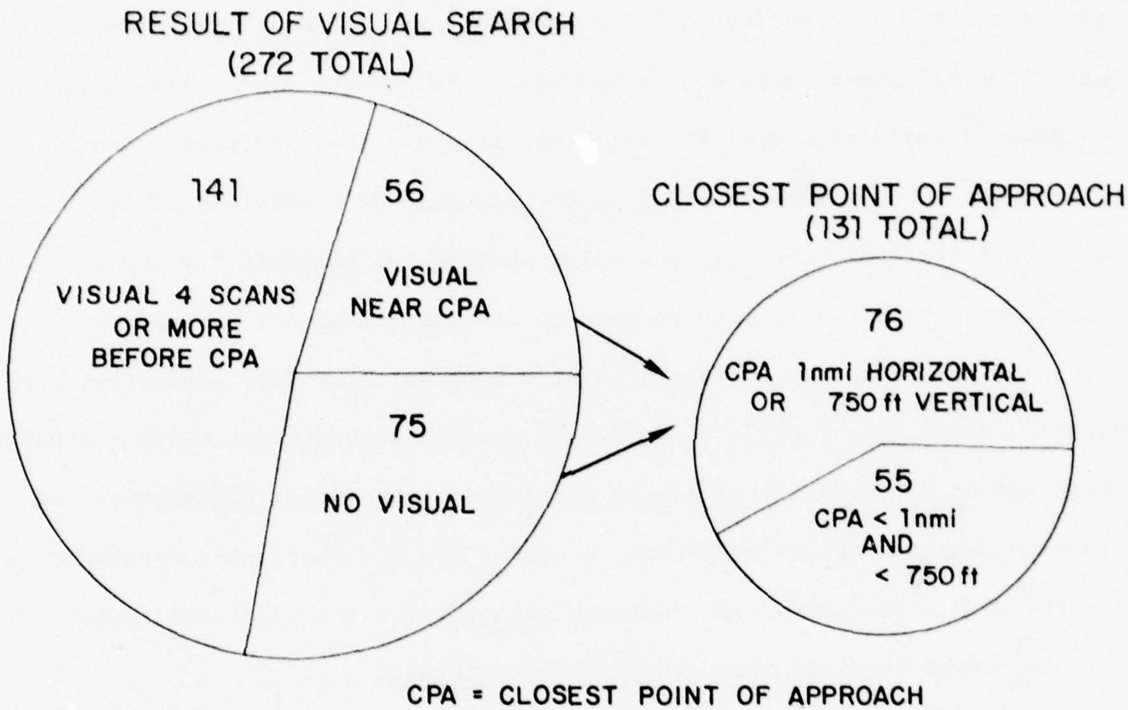

Fig. 5-5. Selection of cases of late or missing visual acquisition for aircraft which approached close to each other.

closest approach was greater than 1 nmi horizontally or greater than 750 feet vertically. These cases do not represent acquisition failure for close approaches. However, 55 cases remain in which closest approach was within 1 nmi and 750 feet. When the crossing angles and approach bearings for these 55 cases were examined, (Fig. 5-6) it was found that all but 8 occurred at larger crossing angles above 120 degrees (where T_a is marginal) or with obstructed approaches. Four of the 8 failures were due to inadequate PWI search time followed by IPC commands which required pilots to turn in a way that prevented visual acquisition. One failure occurred in the presence of a workload distraction. One was attributable to an airline pilot who did not normally fly see-and-avoid and performed very poorly with respect to utilization of the PWI display. One of the remaining two failures was at a marginal T_a value. The other occurred with four scans of FPWI followed by a command sequence for which the pilot complained of having difficulties in pushing the acknowledgment button. Acquisition failures appear to be due to either low T_a, obstructed approach, or workload distractions. IPC commands can distract the pilot and force him to maneuver in a way that produces obstruction.

5.2 Visual Separation Assurance

The subject pilot flight tests sought to determine the manner in which typical pilots flying under visual flight rules would utilize the IPC system. In accepting such service, pilots were asked to modify several practices which they were comfortable with and, on occasion, to allow the evaluation of the IPC system to override their own evaluation of the conflict situation.

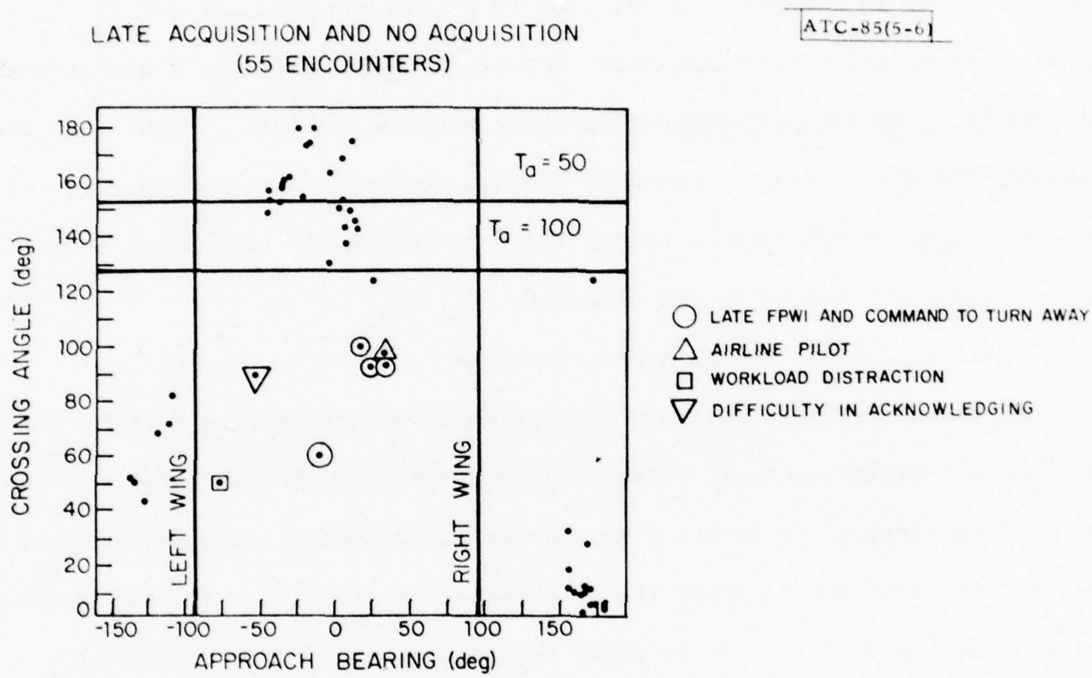

Fig.5-6. Characteristics of encounters with late or missed visual acquisition (55 encounters).

In order to understand and properly interpret pilot reactions to IPC, it was necessary to understand the manner in which pilots were accustomed to providing visual separation in the current VFR environment. The description of visual separation assurance provided in this section is based upon information derived in two ways. First, the 80 pilots who participated in the flight test program were questioned in post-flight debriefings concerning the acceptability of IPC performance and their replies provided insight into their concerns and motivations. Secondly, a small number of missions were conducted in which pilots were asked to choose their own encounter resolution maneuvers without being influenced by IPC commands.

5.2.1 Common See-and-Avoid Practices

VFR pilots provide their own separation from other aircraft utilizing the "see-and-avoid" concept. These pilots spend much of their time scanning surrounding airspace to locate other aircraft. Passengers are encouraged by the pilot to scan and to alert the pilot to other aircraft. Traffic advisories are provided to VFR aircraft by radar controllers upon request and on a workload permitting basis. These advisories enhance the uncontrolled pilot's awareness of nearby aircraft.

When the pilot visually locates another aircraft, he judges whether it is an immediate threat or is likely to become a threat to own aircraft. Any aircraft which constitutes an actual or potential threat is kept in visual contact. The pilot is always concerned with whether or not the pilot of the other aircraft has seen him or is aware of his presence.

The pilot continues on course until able to ascertain the relative flight path of the other aircraft. In most cases, it becomes clear as the range decreases that the aircraft will miss by an adequate margin in either the horizontal or vertical plane. When the traffic is non-threatening, and is seen to be clearly diverging, the pilot is willing to break visual contact. But if it appears that the path of the other aircraft will bring it too close to own aircraft (an individual pilot judgement), and if the pilot of the other aircraft has not started an evasive maneuver (another judgement), the pilot responds with an avoidance maneuver. This avoidance maneuver tends to be a gradual one during which the pilot maintains visual contact at all times. In almost all cases, separation is provided by a maneuver of only one of the two aircraft.

5.2.2 *Visually Controlled Avoidance Maneuvers*

A knowledge of the type of avoidance maneuvers executed under visual control provides insight into several aspects of pilot/system interaction. Pilot acceptance of IPC control is closely related to whether or not the system is perceived as generating commands which are reasonable when compared with the pilot's visual evaluation of the encounters. A limited series of PWI-only missions were conducted in order to determine the timing and directions of visually controlled avoidance maneuvers in tests unbiased by the presence of IPC commands. The PWI service was provided primarily to enhance

pilot awareness of nearby traffic, thereby making the data collection process more efficient (pilots unaware of near-miss situations can not react). However, the manner in which PWI was used provides additional insight into its use in the complete IPC system and is of interest in light of suggestions for PWI-only service as an implementation phase of IPC. Comments upon the effectiveness of such a system can be found in Section 5.4.

PWI-Only Test Methodology

The PWI-only flights were conducted when visibility was greater than three miles. For these flights, subject pilots were briefed to fly the drone over a specific course requiring about one hour of flight. They were briefed to utilize the PWI to locate traffic and provide their own separation when necessary, reacting as they would normally. The tau threshold value for the flashing proximity warning was 45 seconds. Approximately six near-miss approaches were executed during the hour flight. The interceptor test pilot was instructed to establish sufficient altitude separation for safety and to delay execution of avoidance maneuvers whenever possible. This placed the burden of providing additional separation upon the subject pilot. Eleven subject pilots participated in these flights and data were collected on 80 encounters. Of these encounters approximately 10 percent were unplanned conflicts with itinerant ATCRBS Mode C aircraft encountered in the test area.

Maneuver Plane Chosen

In 42 PWI-only encounters the pilots maneuvered to avoid. The choice of maneuver plane was as follows:

horizontal only:	18 cases (42.9%)
vertical only:	13 cases (31.0%)
horizontal and vertical:	11 cases (26.2%)

The data indicates no overwhelming preference of one maneuver plane as opposed to the other. It appears that the choice of maneuver plane is partially a function of the pilot's perception of the relative trajectory of the threat. Pilots seemed to prefer to turn to pass behind traffic which was crossing their path ahead of them. But if an existing altitude separation could be perceived, they were likely to attempt to increase it.

Maneuver Magnitudes

The avoidance maneuvers executed by pilots seldom involved rapid or abrupt accelerations. Typical horizontal maneuvers consisted of a 10-30 degree heading change (see Fig. 5-7). After executing such heading changes pilots then flew straight unless it became obvious that something more was required. In the vertical dimension pilots tended to change altitude until they could see that vertical separation was guaranteed. Normally this required an altitude change of about 300 feet or less. Figure 5-8 provides the distribution of altitude changes observed during PWI-only encounters.

Separations Accepted by Pilots

No regulation exists which requires maintenance of a standard separation between aircraft operating under see-and-avoid. See-and-avoid pilots tend to get fairly close to small or slow aircraft whenever they can perceive that no collision threat exists. They maintain greater distances from larger or faster aircraft since their control of these situations is less certain. The minimum acceptable separation from traffic is thus a matter of individual pilot preference and judgement. Most closest approaches observed in the PWI-only encounters were well within the minimum values IPC uses as range and

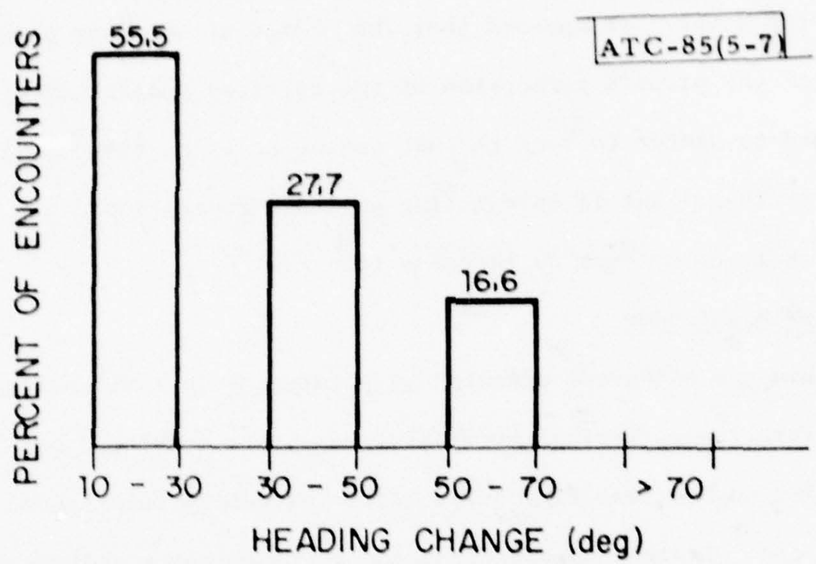

Fig. 5-7. Maximum heading change of aircraft during PWI-only encounters.

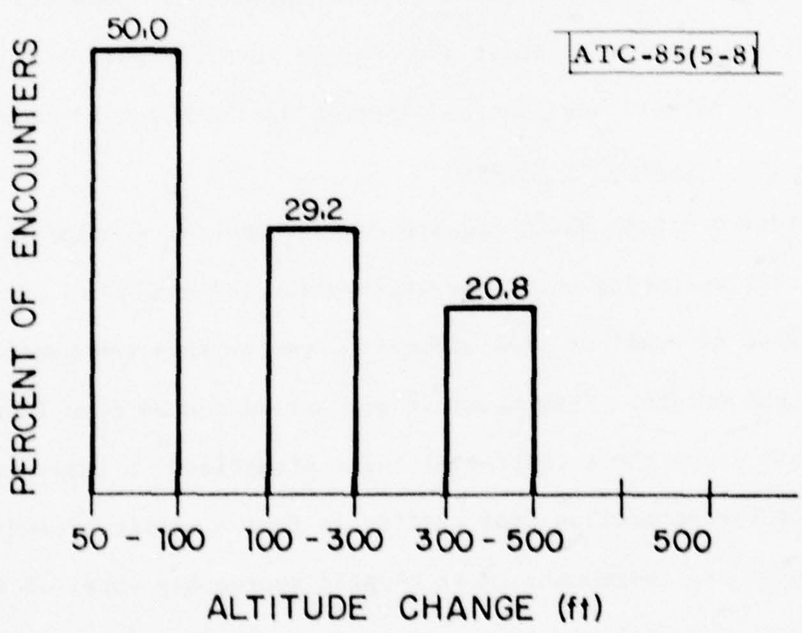

Fig. 5-8. Maximum altitude change of subject aircraft during PWI-only encounters.

altitude separation thresholds. The closest approach values resulting from PWI-only encounters in which the subject acquired the traffic visually and IPC command thresholds (tau < 30 seconds) were violated are shown in Fig. 5-9. Pilots maneuvered in 59 percent of these encounter situations. The distribution of closest approaches for cases where the pilot maneuvered and for those where no maneuver was detected are similar. This fact supports the contention that pilots did not continue to maneuver until some predefined separation was guaranteed. Instead they made limited magnitude corrections, and monitored the threat visually until it was perceived that no collision would occur. Over 80% of the subjects exercising see-and-avoid came within a half mile horizontally and 400 feet vertically. The IPC algorithm thresholds for positive commands are a half mile horizontally and 1000 feet vertically (500 feet vertically for VFR-IFR pairs). Differences between visual and automated system standards are to be expected. A perceived altitude separation of 200 feet is adequate when confirmed visually, but additional altitude separation may be required due to measurement inaccuracies for any system based upon Mode C barometric altitude reports.

Maneuver Effectiveness

In some instances pilots adopted an iterative approach to avoidance. They made limited magnitude maneuvers and then flew straight and level in order to determine whether or not they still appeared to be on a collision course. In the few cases where the initial maneuver did not resolve the threat, another maneuver was executed. The early visual acquisition brought about by the presence of PWI allowed this method of avoidance to be quite effective. Un-

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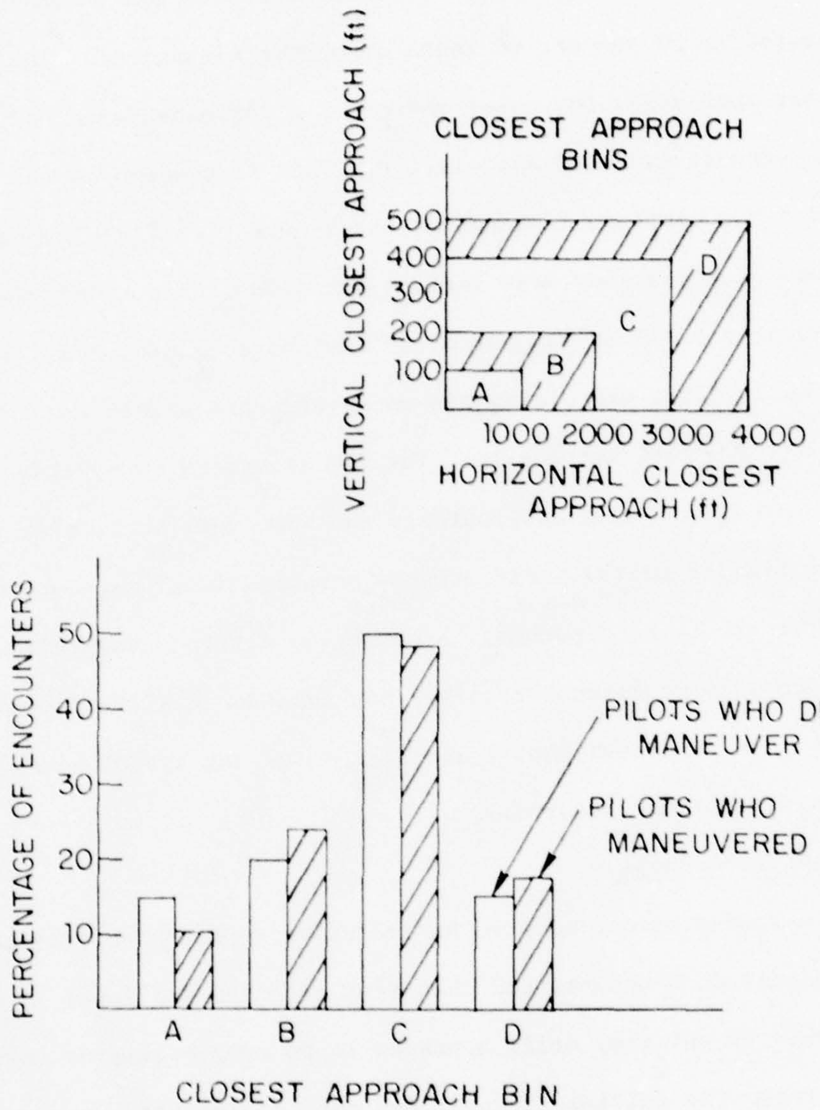

Fig. 5-9 Closest approach analysis for PWI-only encounters with pilot visual acquisition.

fortunately it can not be inferred that the same level of effectiveness would result in encounters without PWI in which pilots are startled by sudden appearance of traffic at close range and must hastily choose the maneuver upon which their ultimate safety depends.

Ineffective maneuvers can arise when the pilot misperceives the relative path of the threat. One visual "illusion" which has been observed in flight tests arises when the interceptor is significantly faster than the drone and is crossing in front. The subject pilot perceives that the interceptor is *further from the point of* collision than is his own aircraft, but he does not perceive the greater speed of the interceptor. Consequently, he may conclude that he is passing in front of the interceptor, and that a turn behind maneuver cannot be executed. He may then turn away and decrease the miss distance (Example 29 of Appendix C illustrates this phenomenon). In the few instances in which this phenomenon was observed, the pilot soon realized that the turn was ineffective and then executed an alternative maneuver (halting, reversing, or maneuvering in the vertical plane). The fact that the pilot can visually monitor the effectiveness of his maneuver provides an important measure of protection against incorrect choice of initial maneuver directions.

5.3 Pilot Response to PWI Service of IPC

This section reports on the pilot response to the proximity warning portion of IPC under normal flight test conditions for which both PWI and IPC commands were available. Pilot response to PWI prior to visual acquisition of the threat and pilot response subsequent to visual acquisition are discussed as separate topics. Other results in the area of PWI design and utilization are presented.

See-and-avoid pilots who must provide their own separation from other aircraft were very receptive to any system that would aid them in locating nearby traffic. The enhanced acquisition capability* provided by PWI was greatly appreciated. Many times pilots stated that they would never have seen the traffic if PWI had not pointed it out. This was true in many cases of potential near-miss situations. Pilots expressed surprise at how close the traffic approached prior to PWI without being noticed. In such cases the traffic was not necessarily considered an immediate threat when the pilot located it. Rather, the pilot was surprised that his normal search procedure failed to detect traffic which was well within optical detection range.

5.3.1 Pilot Use of PWI Prior to Visual Acquisition

Prior to visual acquisition or commands, a pilot's only information about the threat is contained in the PWI indications. The reaction of pilots to unacquired threats was dependent upon whether or not the threat approach bearing was in their field of view or was obstructed by the airframe. Pilots tended to be relatively unperturbed by unacquired traffic at unobstructed bearings. The prevalent attitude was that the traffic would be seen if it were a threat. This attitude may be conditioned by experience with today's ATC advisories which often alert pilots for aircraft which never approach close enough to be considered a threat or even close enough to be seen. On the other hand, pilots were apprehensive when alerted by PWI indications at bearings for which the airframe blocked their view. They were uncom-

*A quantitative assessment of the improvement in acquisition performance was presented in Section 5.1.

fortable knowing that traffic was nearby but not being able to visually monitor the direction of approach. Pilots often stated that they would greatly appreciate being informed of the range to the traffic under these conditions so that they could monitor the separation and rate of closure. For some pilots the unease was alleviated by the knowledge that the IPC system would transition to higher alarm levels (i.e., flashing PWI or commands) before a collision could take place. But such solace was prevalent only in pilots who anticipated and had confidence in the effectiveness of the eventual IPC commands. Pilots who had experience late or ineffective commands felt that visual monitoring was required.

Airframe blockage was observed most frequently in overtaking (tail chase) encounters when the threat was at the 5, 6, and 7 o'clock PWI positions. But blockage is a function of the individual aircraft window arrangement and airframe construction. The blockage effects of high wing and low wing designs are different. Furthermore, pilots indicated that if weather or clouds had obstructed their view, they would have had concerns similar to those produced by airframe blockage.

Pilot Maneuvers Due to Unacquired Threat

The uncomfortable feeling caused by airframe blockage was translated into a positive reaction by many pilots. This was especially true when ordinary PWI's persisted for several scans (as in slow overtake situations) or when the flashing PWI was received. (The pilots were briefed that the flashing PWI indicated an immediate threat and that when such an alarm was

received they should attempt to locate the intruder and be prepared to resolve the situation). Observed reactions generally took the form of a maneuver toward the PWI bearing in an attempt to locate the intruder and to assess the situation (see Example 30 of Appendix C). In the case of PWI's from directly behind (6 o'clock), pilots sitting in the left seat would often momentarily bank left to be able to glance over their shoulder to locate the traffic.

Effect of Maneuvers Prior to Visual Acquisition

Maneuvers executed when the pilot did not have a visual sighting of the intruder often worsened the situation and decreased the ability of IPC to resolve the encounter. Straight and level encounters were turned into maneuvering encounters with all the attendent resolution difficulties described in Section 4.5. Miss distance and time to collision were reduced and tracker lag was induced. Many times these maneuvers took the drone directly into the path of the intruder (see Examples 30 and 31 of Appendix C).

Pilot Interpretation of PWI Information

When visual contact was lacking, pilots attempted to visualize the threat on the basis of PWI position and the history of the PWI alert. Because PWI information is not adequate for this task, plausible assumptions were made to complete the picture. Although they were cautioned in the pre-flight briefing that the PWI should be used as an acquisition aid only, many pilots felt compelled to act on the basis of their interpretation of the PWI data. When their assumptions concerning the missing information were wrong, their actions were often counterproductive.

The information content of the PWI is determined primarily by algorithm thresholds and display design. The current PWI information consists of threat bearing, relative altitude, and flashing/non-flashing status. Major limitations in information content are as follows: (1) the co-altitude PWI position tells the pilot only that the threat is within 500 feet of own aircraft, but not whether the threat is above or below own altitude. This altitude ambiguity leads to misinterpretation. Pilots were observed to maneuver vertically without a visual sighting in response to a co-altitude PWI indication even though this maneuver could be taking them toward the altitude of a threat separated by 400 or more feet in altitude. Some pilots who were changing altitude were observed to level off upon receiving co-altitude PWI's. Occasionally this produced an accelerating threat which would have been averted by continuation of the altitude rate. (2) Pilots cannot infer range to the intruder since the PWI has a tau threshold for which range varies depending upon whether it is a slow overtake situation or a head-on encounter. Furthermore, the tau threshold values are varied according to differences in transponder equipage and flight rules. (3) Pilots often visualize an avoidance maneuver toward the bearing location of the PWI alert as unproductive and a maneuver away as constituting avoidance. (Although as was previously stated, some pilots will turn toward the PWI in an attempt to acquire rather than attempt to avoid on the basis of PWI location). The shaded region in Fig. 5-10(a) indicates possible bearing loci for an aircraft producing a PWI indication at one o'clock. If the encounter locus is at A then a turn by

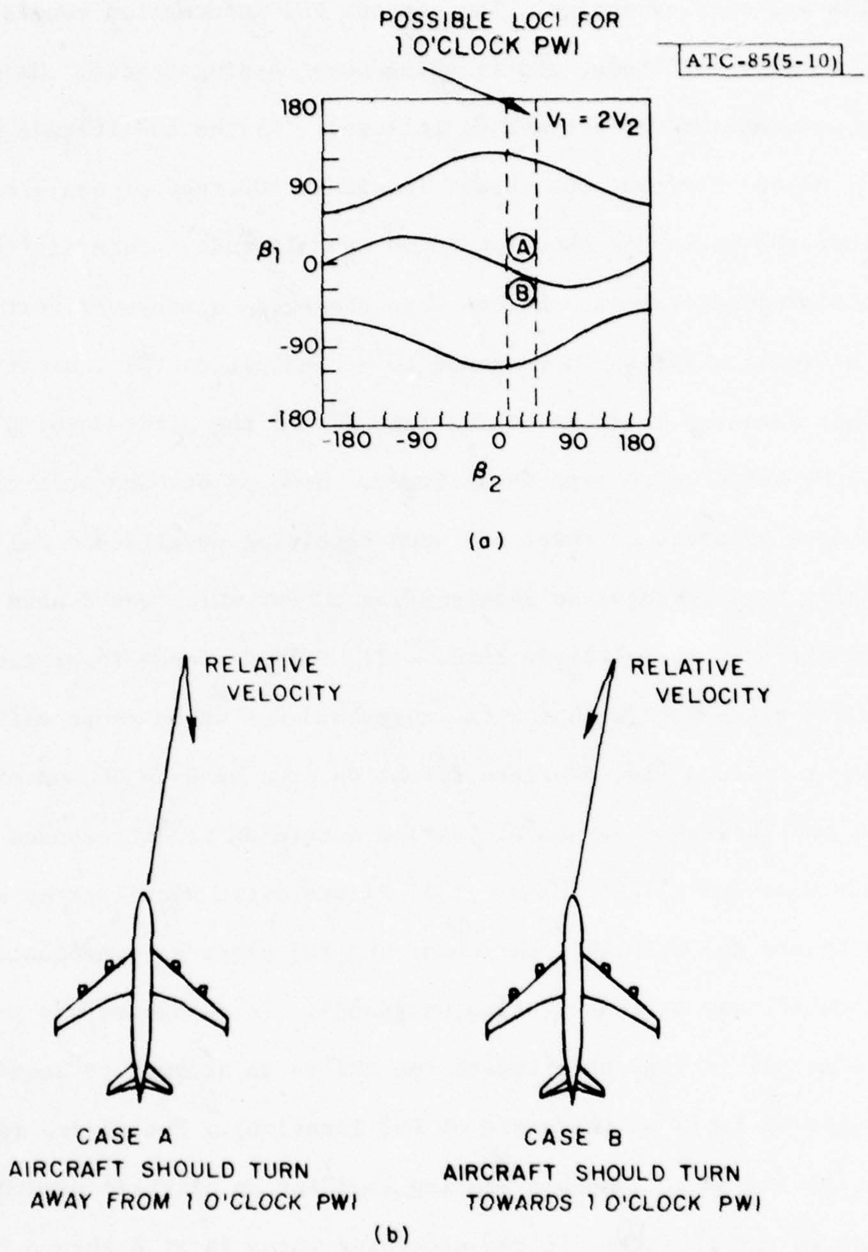

Fig. 5-10(a,b). PWI location does not allow determination of directions in which it is safe to turn.

aircraft 2 toward the PWI light (to move the locus toward $B_2 = 0^o$) reduces existing miss and a turn away increases miss. However, if the encounter locus is at B then a turn toward the PWI is advisable and a turn away decreases the miss distance. These specific geometries are illustrated in Fig. 5-10(b).

The kind of information which pilots felt might allow them to better visualize the threat is similar to that provided by controllers when issuing traffic advisories. A typical radar traffic advisory as issued by a controller might be: traffic 2 o'clock, 6 miles, southbound, fast-moving military jet, 6000 feet. Current PWI information does not include such explicit information about the intruder range, flight path, speed, or Mode C altitude. Nor does the PWI indicate which maneuvers would increase the collision hazard. Additional information that might be helpful in the IPC context would be the flight rules the intruder was operating under and whether it was IPC-equipped (and therefore also able to receive collision avoidance instructions).

Effect of PWI Upon Planned Maneuvers

The IPC concept does not forbid pilots from maneuvering in the presence of unacquired PWI-indicated traffic. In flight testing it was found that some pilots are likely to continue existing turns or altitude rates, even if they result in motion toward an unacquired PWI-indicated threat. Example 32 of Appendix C shows a pilot continuing to climb while receiving a PWI indication from a target above. The pilot rationale for this action was that if the climb were dangerous a command to stop climbing or a descend command would be issued. One pilot stated that he would not be interested in searching for the PWI-indicated traffic unless it was indicated co-altitude. He felt that if the

traffic was greater than 500 feet from own altitude it did not constitute a threat. It appears that many pilots will react complacently to PWI warnings for aircraft they cannot locate if they have confidence in the command back-up or if they have searched an unobstructed bearing and found no traffic. Thus PWI warnings should not be viewed as an alternative to negative commands in situations in which maneuvers are truly hazardous.

5.3.2 Other PWI Results

Pilot Use of PWI to Avert Commands

The IPC concept suggests that pilots use the PWI warnings to locate their traffic and provide their own visual separation, thus obviating the need for command generation. The flight test experience has shown that this is not practicable. Only on rare occasions during the testing were pilots successful in averting commands by initiating a maneuver. This was true for several reasons. First, most pilots chose not to maneuver during the period between visual acquisition and commands. As was discussed in Section 5.2.2, see-and-avoid pilots delayed maneuvers until aircraft were close enough to permit adequate visual evaluation of the nature of the threat. IPC commands often came before such evaluation had occurred. Secondly, pilots accepted separations which were substantially less than those which IPC can tolerate. Finally, even if pilots began maneuvers, the delays in aircraft and tracker response did not allow resolution to be confirmed in the (nominal) 15 seconds between the flashing PWI alert and commands.

PWI Accuracy

Pilots commented on discrepancies in intruder position and PWI clock position due to crab angle induced by wind and tracker lag (during turning maneuvers), but were not overly concerned with them. Pilots who were familiar with radar advisories from controllers were aware of similar phenomena and felt that they did not cause any great difficulty.

Mistaken Identity

On a few occasions pilots mistook another aircraft for the one which the PWI was indicating. The misidentified aircraft was normally either beyond the PWI threshold or not included in the IPC system (e.g., non-transponder or non-Mode C equipped). Typically pilots were able to quickly recognize their mistakes upon discovering that the PWI clock position changes did not track the visually acquired traffic or upon realizing that the sighted traffic was not threatening enough to produce the PWI alarm. A quick search then usually revealed the PWI-indicated traffic. The pilots expressed confidence in their ability to distinguish the PWI-indicated traffic from other traffic visually acquired.

5.4 Comments Upon a PWI-Only Service

PWI-only service has been mentioned as a possible implementation phase of IPC. The PWI-only flight tests (described in Section 5.2.2) and the visual acquisition data gathered during the flight test program enable some relevant comments to be made concerning such proposals.

Pilots flying with PWI-only service were much more apprehensive concerning PWI-indicated traffic approaching from obstructed bearings than were pilots flying with full IPC service. There was a greater inclination to turn in order to acquire overtaking traffic. The safety implications of this behavior may be minimal in terms of its effect upon visual separation assurance if the overtaking pilot has acquired and is maintaining visual contact. But such maneuvers are in conflict with the objectives of an automated resolution system which seeks to follow PWI with commands (see Section 5.3.1). Enhanced information content of the PWI advisory may be required to reduce pilot concerns in these situations, and avoid the establishment of modes of PWI usage which are inconsistent with later evolution of the PWI-only system into a PWI/resolution system.

In many cases pilots appeared to be responding to the cues presented by PWI and not acting entirely upon their own visual perception of the situation. In particular, the flashing PWI with its audio alarm created an air of urgency which caused some pilots to react sooner than they would have ordinarily. This theory is reinforced when analyzing the results for those encounters in which the pilots were unable to visually locate the traffic. Sixty percent of the time these subjects maneuvered using the flashing PWI indications to choose maneuver directions. In such cases, an incorrect visualization of the situation (see Section 5.3.1) could result in maneuvers being ineffective or detrimental. Enhanced PWI could reduce the likelihood of a hazardous PWI-induced maneuver and assist the eventual transition to a full resolution service.

See-and-avoid pilots were enthusiastic about the benefits of PWI. The service certainly increases the probability that approaching aircraft will be seen. Such a service would relieve the controller of the need to provide advisories and would guarantee the availability of advisories regardless of controller workload. There is little doubt that PWI-only service would prevent a great many mid-air collisions which currently occur under see-and-avoid conditions. But it must be recognized that such a service is limited in effectiveness. In certain situations (e.g., rapid closure, reduced atmospheric visibility) the visual acquisition performance of the pilot may be inadequate even when aided by PWI. This limitation is most significant for high performance aircraft flying IFR. A second possible limitation is that in certain cases pilots may choose ineffective maneuvers even when acquisition at adequate lead times has occurred. Collisions resulting due to incorrect maneuvers are unlikely however, if the pilot utilizes PWI properly and visually monitors the effectiveness of his maneuver (see Section 5.2.2).

In a few cases, pilots who had wandered from their intended altitude (usually chosen to correspond with the cruising altitude hemisphere rules - FAR Parts 91.109, 91.121) maneuvered to return to altitude upon receipt of a PWI. Although compliance with intended altitude is generally prudent, the resulting maneuver sometimes carried the pilot toward the altitude of the traffic rather than away.

In summary, the data gathered during the flight tests supports the view that PWI-only service can significantly improve see-and-avoid performance and that an acceptable PWI-only design is readily achievable. Performance can be improved by enhancing the information content of the PWI advisory.

5.5 Pilot Response to IPC Commands

IPC commands were discussed in Section 4 in terms of the algorithmic objectives. There the principal focus was upon the ability of the logic to choose commands which would avert collisions if pilots complied with commands in a nominal fashion. This section discusses the pilot's ability and willingness to utilize the commands generated by the IPC system to assure separation. Section 4 identified certain cases in which the algorithmic logic failed to achieve its desired objectives. Pilot reaction to commands were understandably unfavorable in these situations. A single algorithmic failure was observed to have a long-lasting effect upon pilot confidence in the IPC system. However, the encounters flown during subject pilot missions were generally chosen to illustrate nominal system performance and not to investigate algorithmic weaknesses. Such flight testing revealed that resolution strategies which appeared highly consistent with the objective of assuring separation were often rejected as unacceptable by the subject pilots. The basis of this difficulty lies in the fact that the IPC resolution logic pursues the goal of assuring separation by decisions based upon radar reports while the pilot is motiviated by other concerns and other information. The resulting compatibility problem is discussed in the remainder of this section.

5.5.1 Commands Prior to Satisfactory Visual Evaluation

Subject pilot reactions to commands differed significantly depending upon whether or not the pilot had achieved a satisfactory visual evaluation of the threat. Pilots were generally concerned about PWI-indicated threats

which they had not acquired or which were acquired at a range which did not allow satisfactory visual evaluation of the other aircraft's relative trajectory. Pilots who were unable to acquire in spite of an extended period of PWI-aided search were usually relieved to receive commands which instructed them concerning safe courses of action. Pilots who had acquired a threat but were unable to evaluate it tended to accept commands as the best course of action in view of the fact that the system might have detected a developing collision which they themselves were yet unable to perceive.

Turns Toward PWI Bearings

When instructed to turn toward the PWI indicated bearing of an unacquired threat in order to resolve an encounter, several pilots felt that something was wrong. They felt that a left turn could not be correct if the other aircraft was on their left. It did not occur to these pilots that the indicated traffic could be moving left to right and that the position at closest approach could be to the right even though current position was to the left. The IPC concept engenders confusion on this point. Pilots are told to use the ordinary PWI to determine whether the direction which they intend to maneuver is clear of traffic. It is implied that maneuvers away from PWI bearings are safe. Example 33 of Appendix C illustrates a situation in which a subject pilot initiated a turn away from the PWI indication and then receives an IPC command toward the PWI indication. When visual acquisition had occurred in such situations, pilots themselves generally chose to turn toward the PWI indicated traffic. Pilots were also perplexed by negative commands which

prohibited turning away from PWI bearings (Example 34 of Appendix C). It is likely that if the IPC concept were corrected and pilots were briefed to expect such situations before being exposed to the system, they would find these commands acceptable.

5.5.2 Commands After Satisfactory Visual Evaluation

In many encounters pilots were able to achieve a satisfactory visual evaluation of the threat prior to issuance of IPC commands. Such an evaluation was readily achieved when the (3D) separation at command issuance was small due to modest closure rates or due to an approach in the vertical dimension. After obtaining a satisfactory visual evaluation pilots normally felt that they were capable of controlling the situation or that an adequate miss was guaranteed by the existing trajectories. IPC commands which then appeared often conflicted with the pilot's evaluation and were viewed as being unnecessary or unsafe. In such situations some subject pilots were able to suspend their judgement and follow commands. Other pilots modified their response to the commands or refused to follow the commands at all.

Figure 5-11 provides insight into the extent to which visual evaluation capability affected willingness to promptly comply with commands. The figure shows the heading change executed by pilots in the first 16 seconds following the receipt of positive turn commands. Each point is identified according to whether the pilot had achieved visual acquisition at the time of the command. For purposes of discussion, a pilot will be considered to be complying if he altered heading by 30° or more. It can be seen that the

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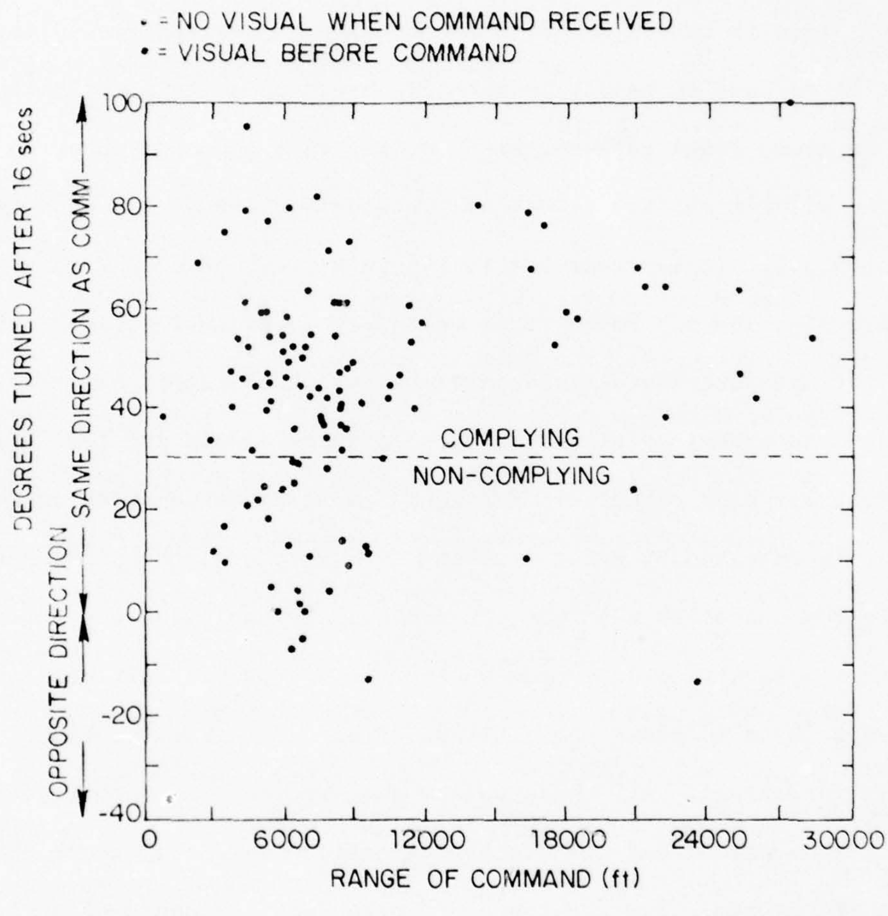

Fig.5-11. Pilot compliance as a function of visual status and range at time of command.

probability of compliance was greatly decreased if the pilot had acquired visually at the time of the command. It should also be noted that pilots appeared to be more willing to comply when the acquired traffic was at longer ranges (greater than 10000 feet) than when the traffic was at shorter ranges. This is consistent with the conclusion derived from pilot debriefings that refusal to comply is normally based upon the pilots visual evaluation at close range rather than a feeling that commands occurred too early.

The pilot's ability to visually evaluate a threat has been discussed in Section 5.3.1. It is important to recognize that at closer ranges the pilot's visual evaluation may be superior to the evaluation of a radar-based algorithm. The pilot may perceive altitude differences which cannot be reliably measured by Mode-C barometric altimetry (which is quantized in 100 foot increments). The pilot may also perceive a horizontal miss distance which cannot be accurately detected by radar tracking. Furthermore, the pilot has access to information unavailable to the IPC system. He can judge the attitude of the other aircraft to determine whether or not it has initiated an avoidance maneuver. He also knows the attitude of his own aircraft, its capabilities, and his intentions. All these points suggest there is justification to the pilot's conviction that his visual evaluation should supercede the evaluation of the IPC system. The existence of infrequent incidents of optical illusion does not intimidate pilots who are consistently successful in achieving visual separation and who feel that an electronic instrument is much more likely to mislead them than are their own eyes.

Maintenance of Visual Contact

It was stated in Section 5.2.1 that one of the most fundamental rules of visual separation was to maintain visual contact with the threat until all danger of collision is past. The commands issued by the IPC system often forced pilots to lose visual contact by requiring them to bank away from the threat or by causing them to turn until the threat was located at their rear. Pilots often considered such maneuvers unsafe since they caused them to lose sight of their traffic. In such instances pilots refused to comply with commands or complied to only a token extent. Examples 35, 36, and 37 of Appendix C illustrate this behavior.

Effect of Observing Other Aircraft's Maneuver

In Section 5.2.1 it was observed that in normal see-and-avoid practices only one aircraft maneuvers to assure separation. IPC normally issues commands to both aircraft. Some pilots did not consider it necessary to maneuver if they observed the other aircraft initiating a maneuver. In such cases the entire burden for resolving the encounter was placed upon the first aircraft to begin avoidance.

Effects of Non-Compliance

Non-compliance by one pilot in an encounter can have undesirable consequences for the other pilot. The complying pilot may be forced to execute a maneuver of excessive magnitude in order to achieve the separation required by the IPC system. Furthermore, the maneuver may be ineffective (e.g., slow speed aircraft in path of fast aircraft). In some cases the compliance

with the command by only one aircraft decreases miss distance and frustrates the separation strategy chosen by the visually motivated pilot. Both pilots often emerge from such an encounter with decreased confidence in IPC commands.

Pilot Suggestions

Pilots made several suggestions concerning possible resolution of the compatibility problem. It was suggested that an "I've got it" button be provided to enable the pilot to accept responsibility for visual separation (analogous transfers of control occur in today's ATC system between controllers and pilots). Pilots also implied that additional information explaining or justifying commands might allow them to accept commands with greater confidence. They also suggested altering the resolution logic to achieve greater agreement with visual separation practices.

5.5.3 *Other Results Concerning* Pilot Response to Commands

Indeterminate Nature of Commands

When a green command arrow was lighted, pilots were briefed to promptly initiate a maneuver in the direction of the arrow and maintain that maneuver until command termination. Pilots were not informed of the magnitude of the heading or altitude changes which would be required. The indeterminate nature of these commands was contrary to normal flying procedure. Pilots wished to anticipate the desired change in order to choose appropriate maneuver rates and to assess the consequences upon other flight objectives (e.g., clearance from clouds or terrain, or deviation from course).

Maneuver Magnitudes

Pilots often complained that IPC commands persisted for too long and required excessive deviations from course. Recall that under see-and-avoid conditions pilots resolve encounters with heading changes of 10-30 degrees. Figure 5-12 indicates the heading changes required by IPC. It can be seen that in about 65% of the cases heading changes of 60^{o} or more were required. A principal reason for such large heading changes is that the IPC tracker may lag far behind the actual aircraft heading and thus commands may continue after the hazard has been resolved. Another factor contributing to large heading changes is the tendency of the system to wait until the aircraft are very close before issuing commands rather than initiating resolution sooner when modest heading deviations would resolve the encounter.

Maneuver Rates

Subject pilots were briefed that when a turn command was displayed a response with a bank angle of 20 degrees would produce safe resolution (Ref. 6 page 12). They were also instructed that an extra margin of safety could be provided by turning with a steeper bank angle. As previously discussed, some pilots modified their response according to their perception of the threat while some others refused to follow the command. Figure 5-13 compares the subject pilot turn rate between the third and fourth scan (14 sec) of horizontal positive commands with the turn rate between the fifth and sixth scan (22 sec) of horizontal positive commands (only cases in which positive commands persisted for at least six consecutive scans are included). The

ATC-85(5-12)

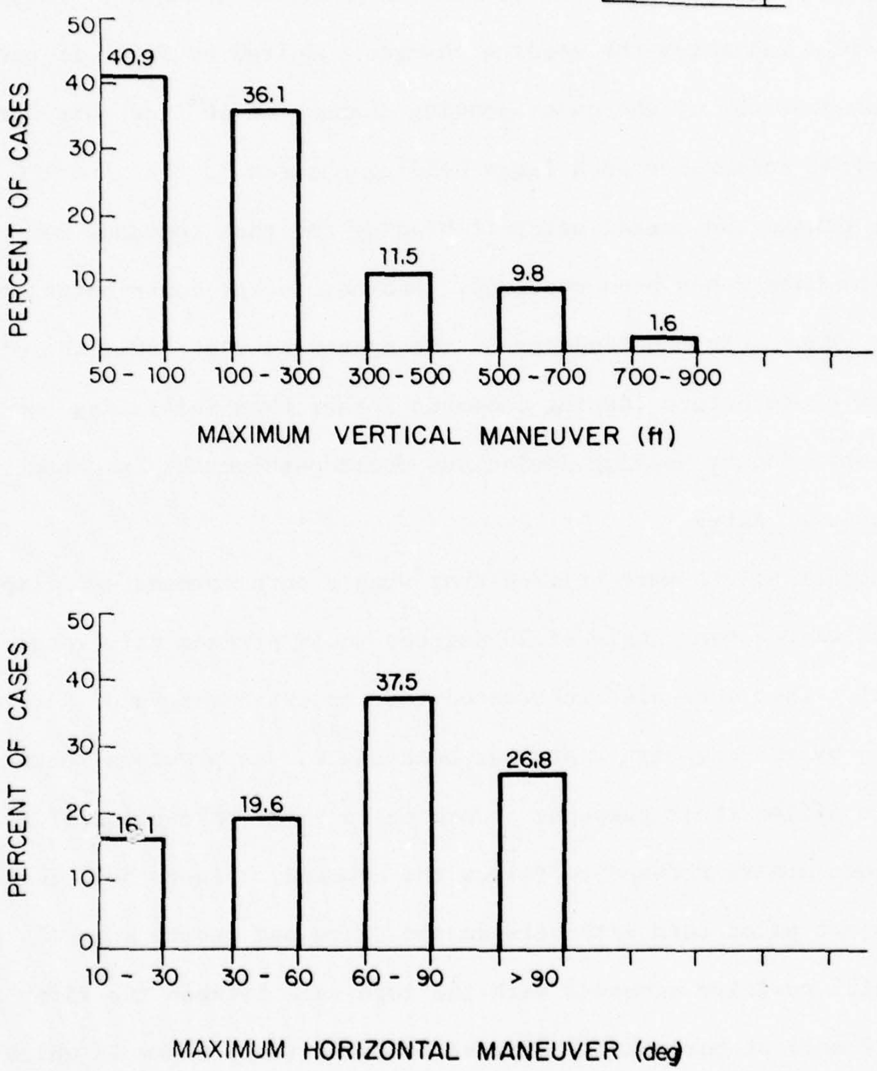

Fig.5-12. Subject pilot maneuver magnitudes during IPC encounters.

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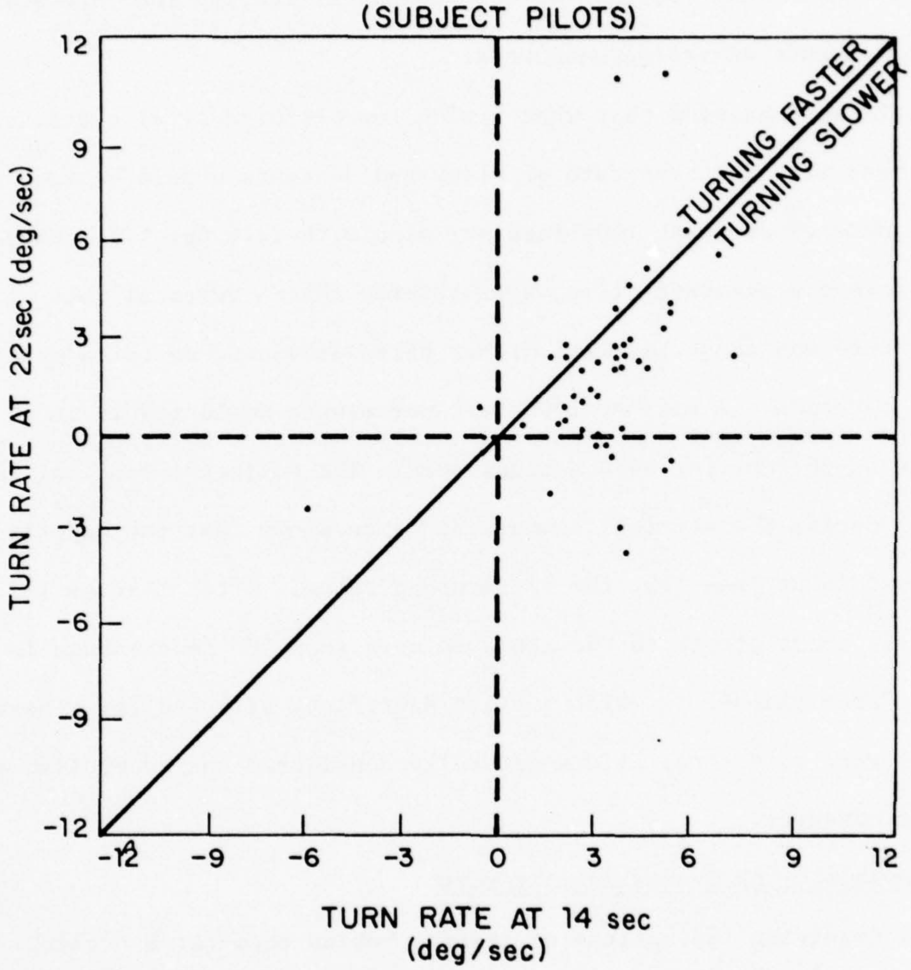

Fig.5-13. Subject pilot turn rates at 14 and 22 seconds after horizontal commands were received.

data reveals a tendency for pilots to respond to horizontal commands after four scans at an average rate of approximately 3 degrees/second, decreasing this average rate thereafter. This tendency appears to be the result of pilots anticipating the termination of commands or feeling they are being required to execute excessive maneuvers.

Subjects were briefed that when flying low performance aircraft, climbs should be made with the best rate of climb and descents should be made using a vertical rate of at least 1000 feet per minute (Ref. 6 pg. 12). When flying higher performance aircraft pilots were briefed that a vertical rate of 1000 feet per minute was adequate, with higher rates providing an extra margin of altitude separation. A rate of 1000 feet per minute would result in an altitude change of 66 feet for each antenna scan. The subject's vertical response (Fig. 5-14) during the vertical command sequence shows that the majority of pilots responded at less than the recommended rates. After 8 scans (32 seconds) only about one-third had achieved more than 300 feet change in altitude. "Zoom climbs" in which a pilot sacrifices airspeed for a maximum climb rate) were very rare. Pilots generally considered the zoom climb an undesirable maneuver.

Responsibility of Overtaking Aircraft

Pilots receiving indications of traffic behind them (at 6 o'clock) felt that they should not receive positive commands in this situation -- they felt that the overtaking aircraft should be responsible for the resolution. They preferred that the overtaking aircraft be vectored around the slower aircraft with the slower perhaps being given a negative command to prevent an inadvertent blunder into the traffic.

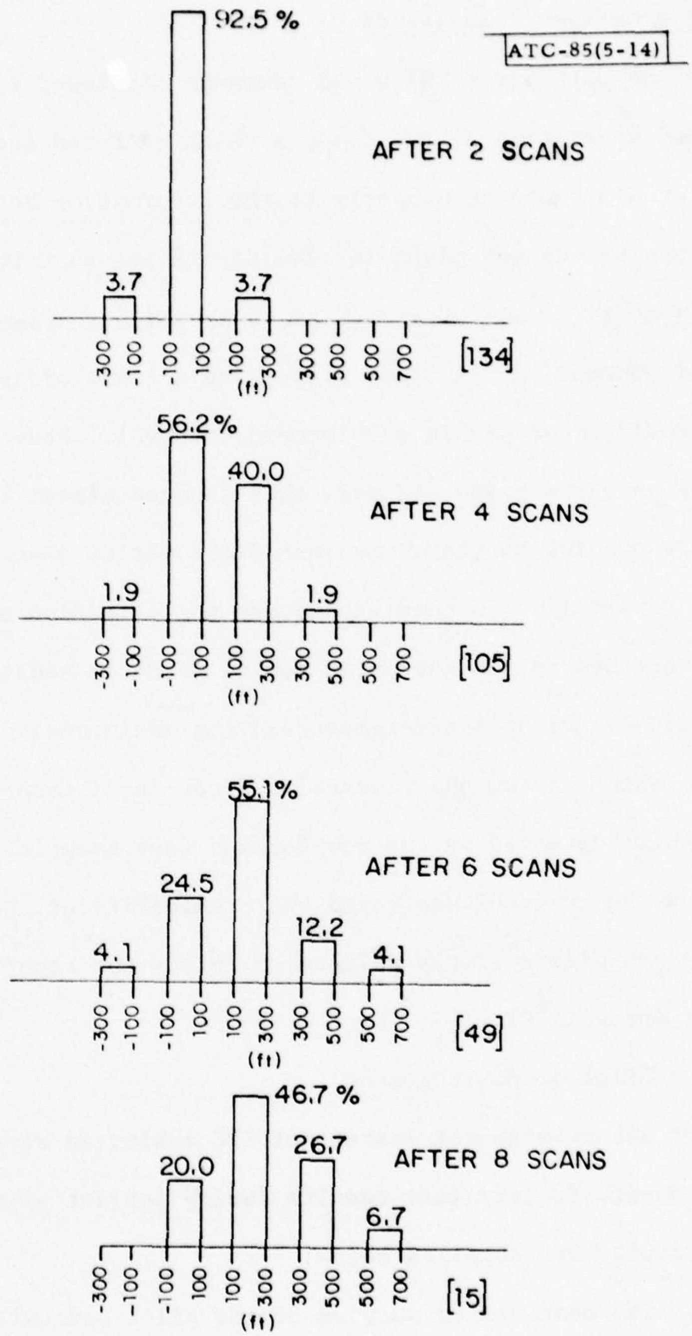

Fig. 5-14. Subject pilot response to IPC vertical commands.

Confusing Message Transitions

In some encounters the PWI's and commands displayed to the pilot underwent rapid and counter-intuitive changes which confused the pilot and made it impossible for him to react properly to the information being displayed. A common sequence of changes might involve displaying an initial ordinary PWI then a flashing PWI, a negative command, a positive command in one plane, an additional command in the other plane, and a final ordinary PWI. All these transitions could occur within a 30 second interval. Many command states persisted for only two scans and were thus changed almost before the pilot could begin responding to them. Serious difficulties arose in connection with command reversals. In some encounters the direction of a horizontal command was reversed on the same scan during which an additional vertical command was added. Pilot's sometimes read the additional vertical command but failed to note the command reversal and continued turning in a direction opposite to that requested by the new command (see Example 38 of Appendix C). At other times the reversal destroyed the credibility of the system's resolution strategy and pilots simply refused to follow the reversed command (see Example 39 of Appendix C).

5.5.4 Pilot Acknowledgement

The pilot acknowledgement feature of IPC exhibited several deficiencies which led to unsatisfactory test results during subject pilot testing. Areas of major difficulty are detailed below:

Concept: The meaning and purpose of the pilot acknowledgement were never clearly defined in a consistent concept statement. The IPC algorithm

document (Ref. 2) states that "Each IPC 'do' or 'don't' message is acknowledged by the pilot activating a 'will comply' or 'won't comply' switch...". Since the inception of the flight test program other statements and documentation have substantially altered the above concept. First, the "won't comply" switch has been eliminated, thus allowing the pilot only a single affirmative response option. Secondly, the "will comply" meaning was eliminated. Pilots were briefed that commands were mandatory and they were expected to acknowledge every command, complying with that command to the extent practicable. Thus pilots acknowledged even when they could or would not comply at all. These changes resulted in the acknowledgement button losing most of its information content and becoming little more than a manual duplication of the DABS technical acknowledgement feature (simply meaning "message received"). This point is shown clearly in Fig. 5-15 which presents the distributions of turn magnitudes executed by acknowledging and non-acknowledging pilots. The amount of information in the acknowledgement is determined by the extent to which its presence alters our a priori estimate of the distribution of pilot responses. It can be seen from the figure that the distribution of turn magnitudes is essentially independent of whether or not the pilot acknowledged.

Cockpit Implementation

The flight test implementation of the pilot acknowledgement feature was modified during the testing to reflect the concept changes mentioned. For example, when the acknowledgement had a "will comply" connotation the aural alarm was sounded for only a fixed period following the appearance of commands. When it was decided that acknowledgement should imply only "message received"

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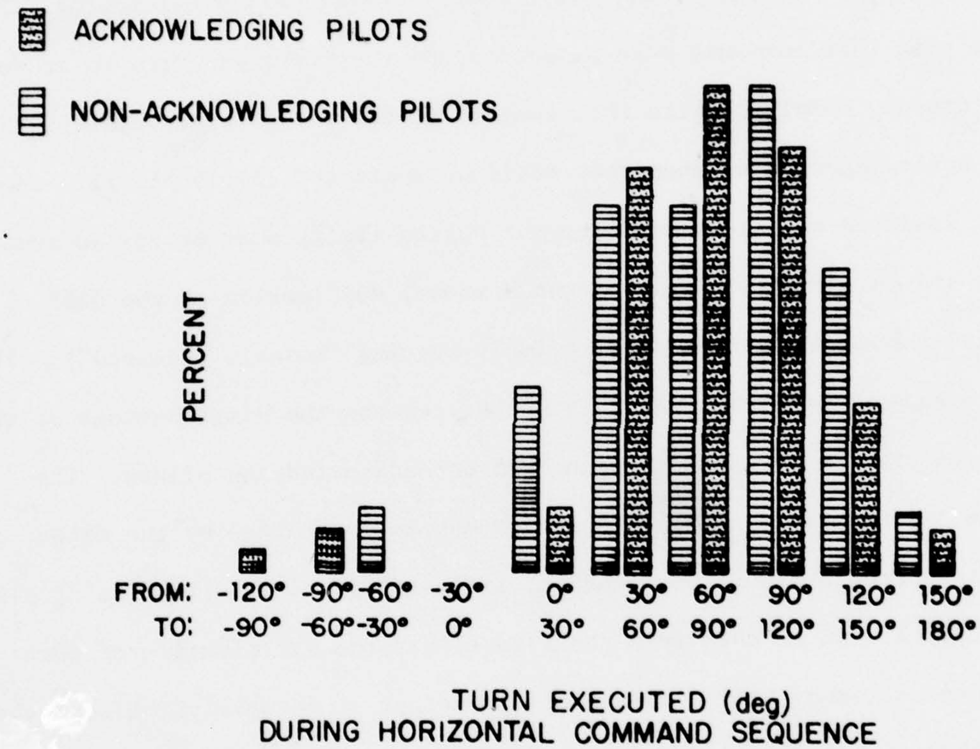

Fig.5-15. Relation of acknowledgement status to turns executed by subject pilots in response to IPC horizontal commands.

the aural alarm was sounded continuously until the pilot acknowledged. This resulted in pilots pushing the button to silence the alarm.

Other factors modified during the testing included the location of the button, its size, and the feedback which tells the pilot whether the button has been properly pushed. Some pilots objected to having to return their attention to the instrument panel in order to locate and push the button. Others stated that the button was too small, poorly located (on the IPC display), poorly lighted, and did not provide a physical indication ("click") when properly activated. A larger button providing the requested feedback was placed within easy reach on the yoke in each of the test aircraft. This revised installation did not fully resolve the issue.

Pilot Workload Considerations

The pilot's successful use of the acknowledgement button depends upon workload constraints. There was concern that the effort of acknowledging would delay the initiation of the avoidance maneuver. Therefore, pilots were briefed to push the button after the avoidance maneuver had been initiated. Under the stressful conditions of avoidance, the button was often forgotten until after the eight seconds allowed for acknowledgement had passed. In the eight seconds following the abrupt appearance of a command a pilot must read the display, decide if he can comply, and put the airplane into the maneuver. Pilots were often attempting to visually acquire the traffic at the same time. The neglect of workload items of lesser importance in this time interval is understandable.

In later tests when the button controlled the continuous alarm it became the first thing many pilots attended to. Pilots pushed the button automatically to silence the alarm before reading the display and executing requested maneuvers.

Algorithm Response

The IPC algorithm tested made radical changes in control strategy based upon the presence or absence of acknowledgement. For instance, if acknowledgements were received from two conflicting VFR aircraft the issuance of additional commands were suppressed for the duration of the declared conflict regardless of the outcome. If a VFR aircraft was in conflict with an IFR aircraft and the VFR failed to acknowledge, additional commands were sent to the VFR and commands to both dimensions were simultaneously issued to the IFR, regardless of whether the IFR threshold values were exceeded.

Benefits

The benefits of any pilot input feature must outweigh the inconvenience associated with its use. These benefits should be apparent if the pilot is to be motivated to use the feature. It was found in testing that pilots felt they received no benefit from acknowledging. In fact some pilots even welcomed the additional command which was usually issued when they were declared non-acknowledging. They felt it provided an additional option for resolving the conflict.

In summary, the pilot acknowledgement feature was not found to be a necessary or beneficial element of the IPC design. It was not satisfactory

according to the following criteria: adequate motivation for the pilot, clear meaning of input, easily used hardware, sufficient time to respond, appropriate use of input by the system.

5.5.5 Cockpit Workload

Cockpit workload was impacted only minimally, in the VFR environment of the flight tests, by proximity warnings or negative commands. However, the issuance of positive commands to avoid a nearby aircraft increased the cockpit workload considerably.

The proximity warning service aided pilots in the performance of their search task, thus reducing their workload. Pilots were able to locate traffic earlier, thus allowing additional time to make avoidance decisions. This provided a sense of increased protection from nearby aircraft. In tests without the tone accompanying the ordinary PWI, pilots complained of having to include the IPC display as part of their instrument scan procedure. Pilots were briefed that this was unnecessary because they should be concerned with these ordinary PWI's only when they intended to maneuver. Then they were to use the PWI to locate the traffic before initiating a maneuver. Pilots, however, preferred to be aware of the ordinary PWI as soon as it was presented. Thus the audio tone accompanying the ordinary PWI was welcomed as it allowed pilots to fly their aircraft without continual reference to the IPC display to determine whether nearby traffic was being indicated. Pilots also felt that negative commands reduced their workload. Knowing how to stay out of trouble with nearby aircraft reduced the time devoted to threat evaluation, especially

when the traffic could not be located visually. Pilots did not consider the negative commands as overly restrictive. Normally they had no intention of maneuvering and the negative command did not affect their flight path. If they did have a desire to maneuver in the direction prohibited, they thought it prudent to delay or modify their maneuver until they had acquired the aircraft causing the command.

The receipt of positive commands in the cockpit caused the workload to increase dramatically. Pilots attempted to evaluate the effect of the commanded maneuvers upon the conflict situation, their own objectives, and the status of their aircraft. Minimal warning situations increased the pilot stress due to the reduced time available for understanding and interpreting the strategy being imposed on the encounter by the command.

When commands were changed several times during a single encounter (due to positive/negative transitions, command reversal, or addition of commands) pilots often felt that they were unable to evaluate the implications of such instructions but were being forced to suspend their judgement and blindly follow the instructions of the system. Pilots who prided themselves upon cautious, methodical flying felt that they were no longer in control of the situation. If pilots were placed in this uncomfortable position by an IPC command which had prevented visual acquisition (see Section 5.4), they often indicated that they would subsequently refuse to comply with such commands. In certain rapidly changing threat situations IPC may have to alter the display more rapidly than is desirable from the human factors viewpoint. But the current IPC resolution logic often exhibits this rapid display change in routine conflicts.

The presence of multiple PWI indications can create a situation in which the pilot's ability to read the display, search for traffic, and interpret displayed information is exceeded.

In summary, single PWI alerts and negative commands appeared to be very compatible with workload constraints and often reduced the normal pilot workload. Positive commands resulted in increased workload. Rapidly changing positive commands and multiple PWI alerts often overloaded pilots and resulted in unfavorable reactions.

5.6 Other Subject Pilot Results

5.6.1 The IPC Display

A single IPC display design was utilized throughout the flight testing since the investigation of alternative cockpit display designs was beyond the scope of the test program. Very little familiarization was required to enable pilots to read the IPC display (Fig. 2.1). Some pilots felt that the display was too elaborate for the amount of information provided. They seemed to feel that a unit with 36 lights should provide more than just threat bearing and the three altitude bins. They often mentioned threat range and above/below threat altitude as desired information (see Section 5.3.1).

Some pilots objected to the red color of the proximity warning lights. They felt red should be reserved for emergency situations and that amber would be a better choice for PWI. The LED lights used were often washed-out by sunlight and therefore unreadable during daylight operations. The LED's were too bright in the dark cockpit during night operations (see Section 5.6.2).

Negative Commands Reinforcing Positive Commands

Green arrows are used to indicate to the pilot the direction in which to maneuver. Each arrow is accompanied by a red X to indicate that a maneuver in the opposite direction is expressly prohibited. Pilots felt this practice was not only redundant and unnecessary but that it cluttered the display thus reducing readability. Pilots who had trained themselves to ignore the red X's and look only for the positive command indications (green arrow) could fail to note a lone negative command which was accompanied by a positive command in the opposite plane.

PWI Audio Alert

During initial testing an audio alert was provided for only the flashing PWI indications. However, many pilots commented that an audio alarm should also accompany the ordinary PWI (see Section 5.5.5).

In later missions a single tone was provided for the ordinary PWI and a double tone for the more urgent flashing PWI. It is possible that a single alarm at the beginning of a PWI sequence would suffice rather than a series of alarms indicating various stages of conflict development.

A volume control for the PWI audio alert is recommended to allow pilots to adjust the amplitude of warning desired. Some pilots were concerned with the distraction associated with many alerts while busy performing critical communication, navigation, and cockpit duties during terminal operations. These pilots could utilize such a control to reduce intrusiveness to an acceptable level.

5.6.2 IPC at Night

Several IPC missions were flown at night in order to explore differences between pilot reactions under daylight and night visual conditions. In contrast to daylight operations, pilots flying at night were consistently able to acquire traffic before PWI indications were received. Aircraft flashing strobe lights or rotating beacon lights were normally visible at ranges of 10 miles or more. However, once acquired, pilots found it much more difficult to visually evaluate the nature of the threat presented by the traffic. In particular, range to the traffic was difficult to estimate. Often several aircraft were visible at once. In these situations the PWI served a valuable function in informing the pilot as to which of the aircraft constituted a threat. But the difficulties of visual evaluation increased the level of concern experienced upon receipt of a PWI or command. Pilots valued commands as a solution to a threat situation which they could not easily evaluate visually, but there was also increased apprehension concerning commands since the effectiveness of the commands was not readily monitored by visual means. Pilots seemed to feel just as strongly as they had in the daytime that maneuvers should not cause them to lose sight of their traffic.

Most of the other results mentioned previously with respect to daytime flying were also observed at night. Pilots felt that the system must be wrong in requiring maneuvers of large magnitude even though they could not always confirm this impression visually. They also attempted to extract as much information as possible from the PWI indications. In this respect they

reacted in a manner similar to pilots flying in daylight who were unable to acquire. They expressed frustration that the PWI was unable to provide them with the range and relative altitude of traffic.

Pilots also commented upon the brightness of the IPC display. They felt that its brightness adversely affected their night vision. Display brightness was not adjustable on the displays used in flight testing and pilots suggested that such adjustability be added.

5.7 Summary of Subject Pilot Results

Subject pilot flights evaluated the reactions of pilots flying under visual flight rules to the PWI and resolution service offered by the IPC system. It was found that the visual acquisition performance of pilots could be mathematically modeled as a non-homogenous Poisson process in which the rate of acquisition is proportional to the angular area of the traffic. Test data indicates that PWI alerts increased the rate of visual acquisition by a factor of approximately 6. Pilot reaction to the enhanced acquisition capability provided by PWI was highly favorable. When pilots were unable to visually acquire indicated traffic, reactions to PWI were mixed. When failure to acquire was due to airframe blockage, pilots sometimes felt compelled to maneuver in order to obtain an unobstructed view of the threat. These maneuvers sometimes resulted in a decrease in existing separation. On some occasions pilots attempted to avoid based upon PWI information which was inadequate for choosing a suitable maneuver. Frustration with the limited information content of the PWI alert was expressed in these situations.

The concept of pilots utilizing the PWI to visually acquire and provide their own separation from traffic, thus eliminating the need for commands was found to be unworkable. Commands were generally generated before the subject pilots were close enough to decide on a course of action, or before the IPC tracking could react to the effects of their maneuvers. Pilots recognized but were not overly concerned with PWI bearing error due to wind induced crab and tracking lag during turns. They expressed confidence in their ability to distinguish the PWI-indicated traffic from other traffic acquired visually.

Conflict resolution using see-and-avoid techniques was investigated in a small number of flights in which pilots resolved conflicts without IPC commands. No overwhelming preference for either vertical or horizontal maneuvers was apparent. When appropriate, pilots preferred a slight turn to pass behind traffic crossing their path ahead of them. Pilots felt it essential to keep the traffic in sight while it posed a potential threat. Conflicts were resolved by one of the aircraft executing a small magnitude maneuver in either the horizontal (10-30 degree heading change) or vertical (change of 300 feet or less in altitude) dimension or some combination of the two. Pilots monitored the effectiveness of these maneuvers visually until the threat had passed. In over 80 percent of the conflicts using see-and-avoid the aircraft closed to within the positive command thresholds of the IPC algorithm. Experimental results revealed that pilots with visual contact felt comfortable even though separation from another similar general aviation aircraft was only 1500 feet laterally or 200 feet vertically.

Pilots responded favorably to IPC commands when they could not locate their traffic or when they had not approached close enough for effective visual evaluation of the threat. But once satisfactory visual evaluation of the threat was achieved, the pilots felt that visual separation assurance should take precedence over automated resolution. Mandatory commands were then felt to be an imposition on their authority, forcing them to relinquish control of readily controllable situations. The commands often conflicted with the pilot's evaluation, and produced a feeling that the commands were unnecessary or unsafe. Pilots objected to being forced to lose sight of the traffic. They were unhappy with executing large magnitude maneuvers and they generally were uncomfortable with being placed into open-ended maneuvers. When one pilot refused to comply with IPC commands, the commands issued to the other pilot could be ineffective, detrimental, or of excessive magnitude.

The above observations involving subject pilots provide considerable insight into the ultimate success of an automated collision avoidance system. Many pilots suggested, and the PWI-only test verified, that they will be comfortable with relatively small miss distances, provided that they can continuously monitor the traffic visually. Some felt strongly enough to recommend that there be an "I've got it" button which the pilot could use to signal the system that he is accepting responsibility for separation from a particular aircraft. It appears that the success of IPC in giving acceptable

advice to pilots will be greatest before visual evaluation when the system clearly knows more about the situation than the pilots. But whenever the pilots obtain a good visual assessment of the threat, automated resolution is likely to be compromised by independent pilot behavior.

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APPENDIX A
RELATIVE MOTION ANALYSIS

A.1 An Aircraft Pair as a Dynamic System

For analytical purposes the motion of a pair of aircraft may be modeled in terms of a dynamic system for which a set of state variables provide a complete description of the state of system at any given instant. The manner in which these state variables change with time under given control inputs is determined by a set of differential equations known as state equations. The particular choice of state variables for a given system is not unique (e.g., many different coordinate systems could be chosen) but the number of independent variables which are required for a system of given complexity is unique. Because analysis of collision avoidance requires only a knowledge of how aircraft move relative to one another, the dynamic system employed in analysis can be simplified in order to utilize the minimum number of variables which adequately describe relative motion. For the analysis which follows it will be assumed that during the course of an encounter aircraft fly at constant airspeeds and that all control over aircraft motion is effected through heading changes (turns). Under these assumptions a description of the relative motion can be obtained with only five state variables. One choice of the five variables which is useful in understanding the effect of control actions utilized range, relative bearings, and airspeeds (see Fig. 4-2). Relative bearings are measured positive clockwise from the velocity vector of the aircraft of interest. The state equations for this choice of variables are:

$$\dot{r} = -V_2 \cos \beta_2 - V_1 \cos \beta_1 \tag{1}$$

$$\dot{\beta}_1 = \frac{V_2 \sin \beta_2 + V_1 \sin \beta_1}{r} - \omega_1 \tag{2}$$

$$\dot{\beta}_2 = \frac{V_2 \sin \beta_2 + V_1 \sin \beta_1}{r} - \omega_2 \tag{3}$$

$$\dot{V}_1 = 0 \tag{4}$$

$$\dot{V}_2 = 0 \tag{5}$$

where ω_1 and ω_2 are the turn rates of aircraft 1 and aircraft 2 respectively.

Because the five state variables provide a complete description of the state of the dynamic system, any other quantity which describes the relative motion can be written in terms of these five. Table A-1 provides state variable definitions of certain other quantities, several of which will be mentioned in the text which follows. The crossing angle, χ, is the heading difference measured positive clockwise with the heading of aircraft 1 as reference. Miss distance, m, is a signed quantity whose magnitude is the separation at closest approach which would result from rectlininear flight at current headings. The sign of miss distance is positive if the range vector rotates clockwise, negative if it rotates counterclockwise.

Natural (Rectilinear) Motion

The first step in understanding the behavior of the dynamic system defined above is to understand the properties of relative motion under rectilinear flight ($\omega_1 = \omega_2 = 0$). Since this mode of flight occurs in the absence of control inputs, we will refer to such motion as natural motion. The

TABLE A-1

VARIOUS RELATIVE MOTION VARIABLES

EXPRESSED IN TERMS OF STATE VARIABLES

(Note: $\gamma = V_2/V_1$)

Variable	Scale Factor	Expression
Miss distance, m	r	$\dfrac{\gamma \sin \beta_2 + \sin \beta_1}{[1 + \gamma^2 + 2\gamma \cos(\beta_1 - \beta_2)]^{1/2}}$
Crossing angle, x	-	$\pi + \beta_1 - \beta_2$
Time to path crossing	r/V_1	$TTX1 = \dfrac{\sin \beta_2}{\sin(\beta_2 - \beta_1)}$
		$TTX2 = \dfrac{\sin \beta_1}{\gamma \sin(\beta_1 - \beta_2)}$
Range rate	V_1	$-\gamma \cos \beta_2 - \cos \beta_1$
Time to closest approach	r/V_1	$\dfrac{\gamma \cos \beta_2 + \cos \beta_1}{1 + \gamma^2 + 2\gamma \cos(\beta_1 - \beta_2)}$
Relative velocity (speed), V	V_1	$[1 + \gamma^2 + 2\gamma \cos(\beta_1 - \beta_2)]^{1/2}$
Tau $(-r/\dot{r})$	r/V_1	$\dfrac{1}{\gamma \cos \beta_2 + \cos \beta_1}$

following properties of natural motion apply to an encounter in which aircraft begin at infinite range and fly to closest approach without turning:

Properties of Natural (Rectilinear) Motion

1. Miss distance and crossing angle are constant.
2. At closest approach the range rate is zero. (Necessary stationary condition for a minimum).
3. The bearing rate is the same for both aircraft (Equations 2 and 3 with $\omega_1 = \omega_2 = 0$).
4. The sign of the miss distance is the same as the sign of the bearing rate ($\dot{\beta}_1$ from equation 2, and m from Table A-1).
5. Between infinite range and closest approach, bearing changes by 90^o. (Obvious from geometry).
6. The bearing rate is small at long ranges and is a maximum at closest approach (Note that $\dot{\beta} = Vm/r^2$).
7. For zero miss distance trajectories the bearing rate is zero.
8. Unequal speed aircraft are always in motion relative to one another, but when equal speed aircraft fly with zero crossing angle, they are in a unique state for which there is zero relative velocity.

A graphical procedure for depicting the relationship between various relative motion quantities may now be introduced. With β_1 and β_2 as ordinate and abscissa respectively, contours of constant value for the quantities of interest are plotted. Construction of two dimensional plots requires that

the plotted quantities be normalized in an appropriate manner. Quantities with units of distance will be normalized to r and quantities with units of velocity will be normalized to V_1. Time units may then be expressed in terms of r/V_1.

The essential properties of natural motion are illustrated in Fig. A-1 using these conventions. Contours of constant crossing angle are simply lines of 45^o slope. Since χ is constant for natural motion (property 1), all changes in bearing which occur as the aircraft fly past each other must result in the locus of the encounter moving at 45^o along the appropriate χ contour. Contours of constant normalized miss distance, $\mu = m/r$, provide further information concerning the nature of this motion. Fig. A-1 miss distance contours for a speed ratio $V_2/V_1 = 1/2$ are provided. For finite miss distances, the initial location of the encounter is near the $\mu = 0$ contour, and the locus converges at closest approach to either the +1 or -1 contour, depending upon the sign of the miss distance. Note that the bearing change which occurs between the $\mu = 0$ contour and the $\mu = \pm 1$ contour is always of magnitude 90^o (property 4). The $\mu = \pm 1$ contours are also contours of zero range rate (property 2). For all points outside these contours, the range is increasing. As aircraft pass closest approach the encounter locus continues to move in the same direction until approaching the $\mu = 0$ contour in the region of positive range rate.

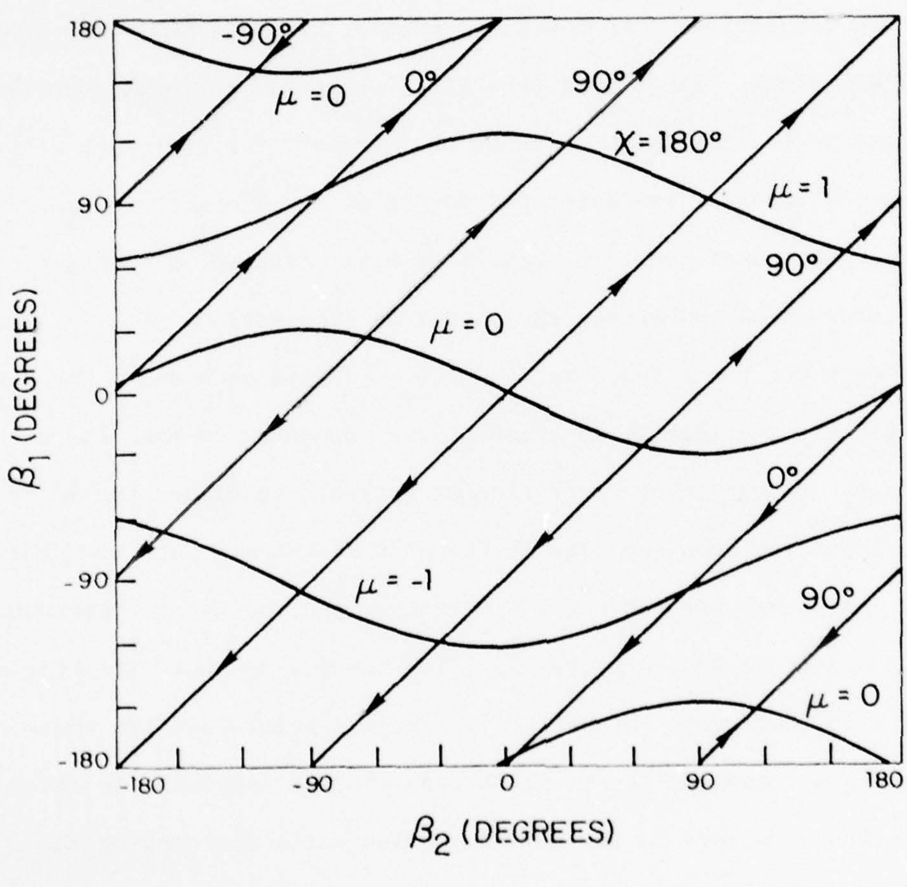

Fig. A-1. Natural (rectilinear) motion defined with reference to contours of crossing angle χ and normalized miss distance.

For zero miss distance encounters the motion of the locus is simply a degenerate case of the motion described above: the encounter locus remains on the $\mu = 0$ contour until zero range and then moves 180° to the zero contour in the region of positive range rate. It should be kept in mind that for natural motion all changes in the m/r value are due to changes in the denominator r and that the miss distance m is constant.

Forced (Turning) Motion

When aircraft turn to avoid collision the forced motion which results alters the miss distance. A trajectory segment containing a turn may be represented in terms of piecewise rectilinear segments as shown in Fig. A-2a. In a dynamic sense, the actual turn which takes place between B and C is concentrated into two turn rate impulses whose integrated sum equals the total heading change. Two properly timed turn rate impulses allow the effect of the actual turn to be modeled exactly in the sense that an aircraft executing the impulsive turns arrives at point C at the same time and with the same heading as an aircraft flying the actual curvilinear path. For most purposes a simpler representation of the effect of turns may be achieved by utilizing a single impulsive turn which occurs with time delay

$$\Delta t = \frac{\tan(\Delta h/2)}{\omega} \tag{6}$$

relative to the time at which the turn actually began. This approximation (see Fig. A-2b) results in the aircraft arriving at point C with the proper

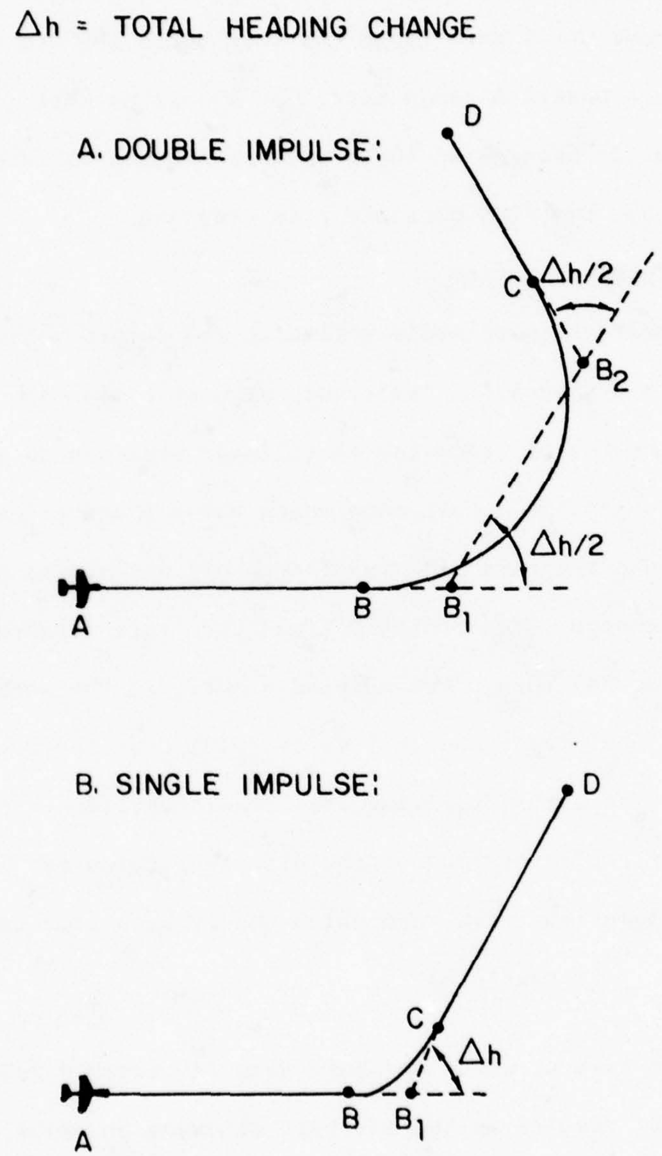

Fig.A-2. Representation of turns in terms of impulsive turn rates.

heading but delayed somewhat due to the difference in path length between the actual and representative flight paths. This error is typically less than 2 seconds for turns less than 60^o, and if both aircraft maneuver each is delayed in a similar fashion so that the net effect on the relative motion tends to cancel. In the examples which follow the single impulse representation will be utilized.

The effect of turn impulses upon the encounter locus in bearing space is obvious: a turn impulse results in an immediate change in bearing with magnitude equal to the (integrated) magnitude of the impulse. Bearing is increased by left turns and decreased by right turns. For plotting purposes bearing change due to forced motion may be distinguished from bearing change due to natural motion by plotting all natural motion as movement along lines of 45^o slope and all forced motion as a sum of displacements parallel to the β_1 and β_2 axes. Figure A-3 is such a plot of a hypothetical head-on encounter which is resolved by both aircraft turning right. Since the range cannot change instantaneously, changes in the m/r ratio which occur under forced motion must correspond to changes in miss distance. In the example the forced motion between points 2 and 3 results in a change in the m/r ratio from -0.20 to -0.82 and thus changes the miss distance by a factor of 4.1. The basic characteristics of the two types of motion used to obtain a complete representation of relative motion may be summarized as follows:

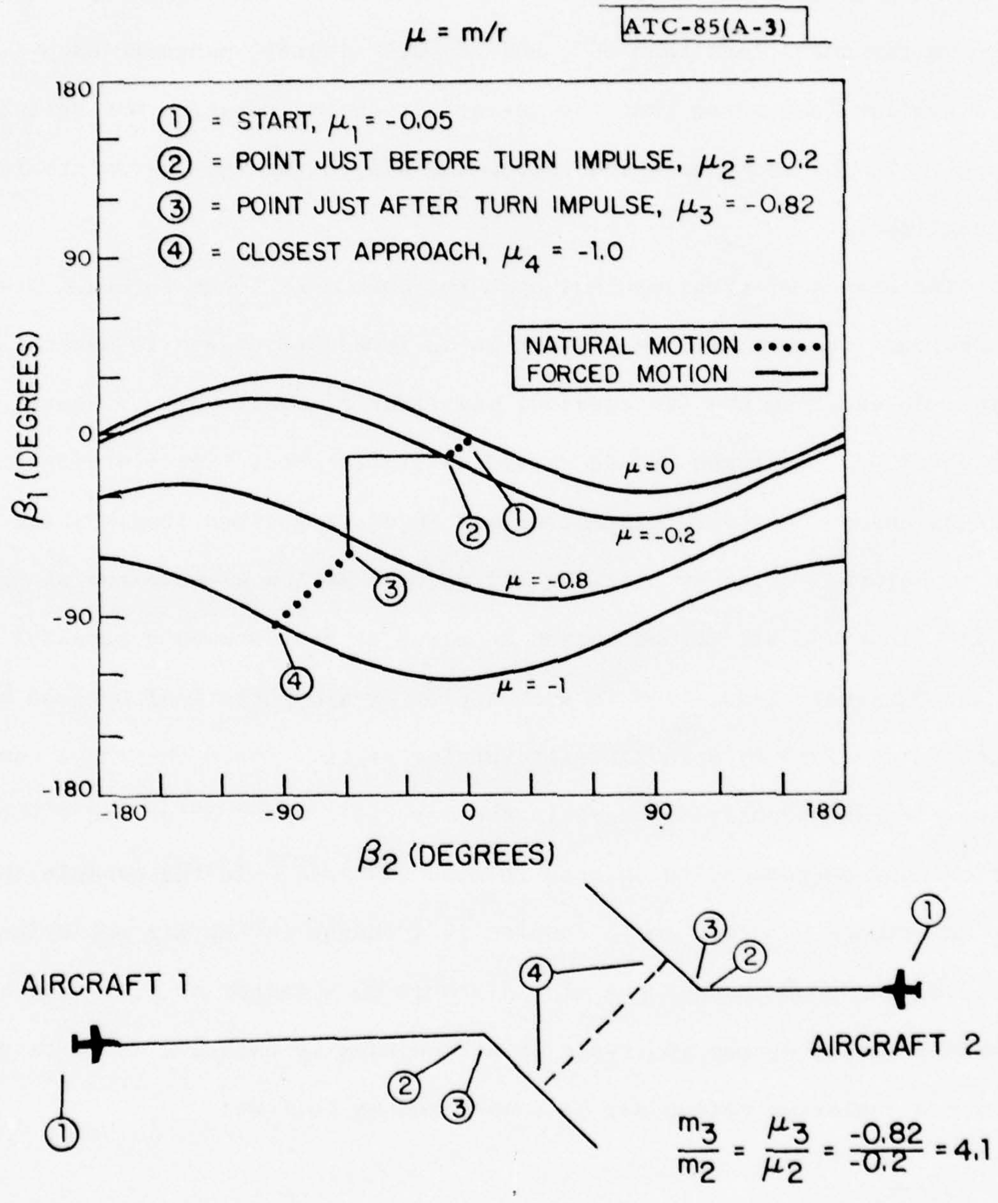

Fig. A-3. An encounter plotted as a combination of natural and forced motion.

Natural Motion	Forced Motion
Rectilinear flight	Impulsive turn
Time Elapses	Instantaneous
Constant Miss Distance	Constant Range
Motion at 45^{o} to axes	Motion Parallel to axes
Bearing rate increases as range decreases	Bearing change equal to heading change
μ ratio between two points equal to inverse of range ratio	μ ratio between two points equal to miss distance ratio

Tau Contours

Table A-1 provides an expression for unmodified tau (range ÷ range rate) in terms of state variables. In this form tau may be plotted in units of r/V_1. The modified form of tau utilized by the IPC algorithm differs from unmodified tau only by the factor $1 - D^2/r^2$ where D is a constant (see Section 4.2). Thus in our bearing space contours of either form of tau are the same except that the actual value of tau corresponding to a contour may differ due to the difference in scale factors. Figures A-4 and A-5 provide tau contours labeled in units of r/V_1. Note that tau is a minimum at $\beta_1 = \beta_2 = 0$, and that the actual value of tau is rather insensitive to bearing near this point. However tau goes to infinity as the range rate goes to zero (at $\mu = \pm 1$). In these regions the value of tau is highly sensitive to bearing. This sensitivity results in erratic tau transitions when heading estimates are changing due to track jitter or aircraft accelerations.

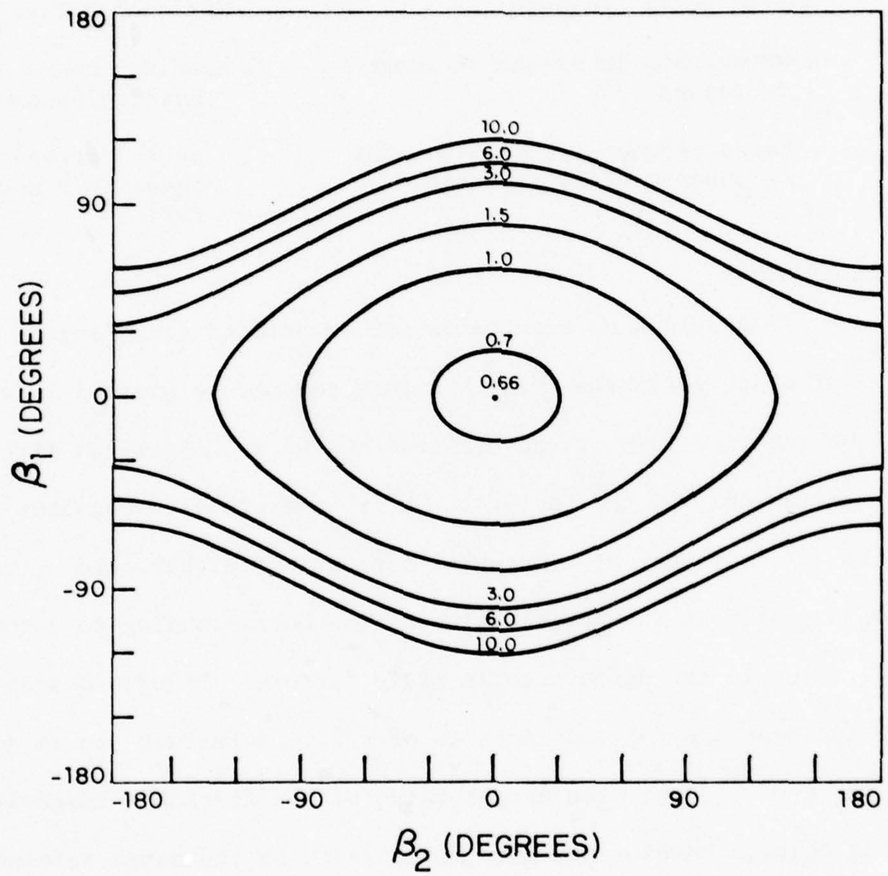

Fig.A-4. Contours of constant tau for 1:2 speed ratio.

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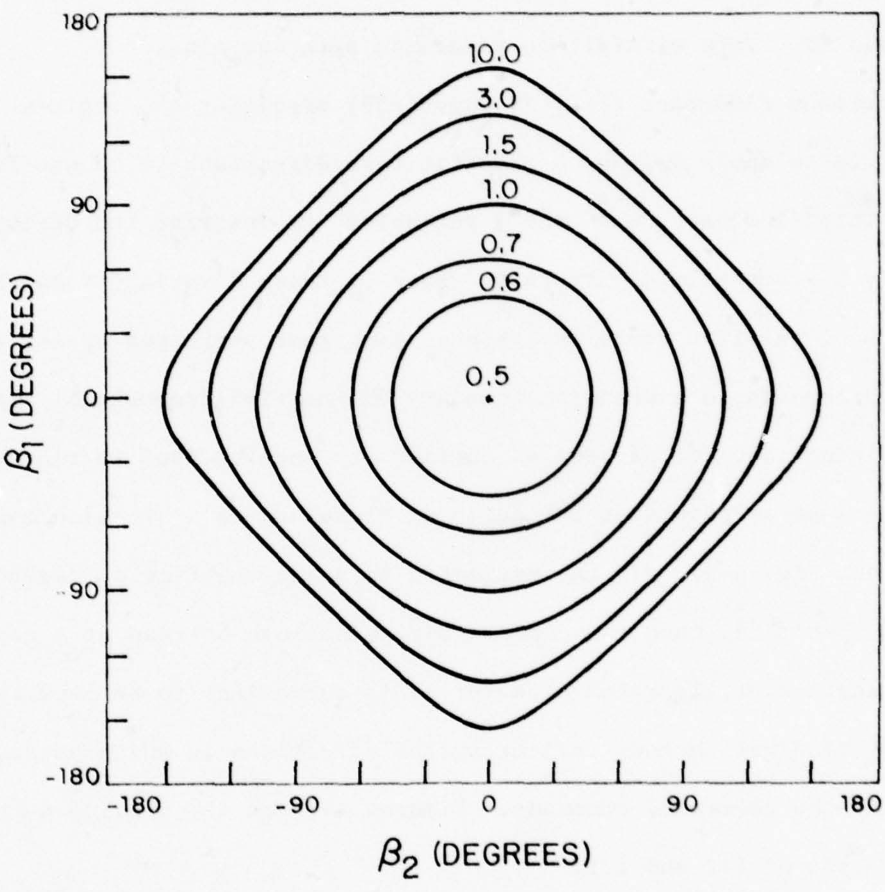

Fig. A-5. Contours of constant tau for 1:1 speed ratio.

A.2 Mapping the IPC Horizontal Command Selection Logic

The IPC horizontal command selection logic used one of three selection rules. These rules may be summarized as follows:

Rule A: Turn aircraft to eliminate closure rate.

Rule B: Turn aircraft to increase the existing miss distance.

Rule C: Turn aircraft to reinforce path crossing.

The algorithm flowchart (Ref. 1, page 5-59) specifies the logic which determines which rule to apply and which specific turn directions to choose for each rule. This flowchart uses some 9 variables* to describe the decision to be made for a given pair of aircraft. Each of these 9 variables can be written in terms of the five state variables. Each test performed by the algorithm then corresponds to a decision boundary in the five-dimensional state space. The plotting conventions adopted earlier can then be used to reduce the many branch and merge points of the defining flowchart to a decision map in state space (see Fig. A-6). If the estimated locus at the time of command generation is specified, then the command directions can be read at a glance. In the evaluation of algorithm behavior it is convenient to replace the right/left notation with arrows indicating the directions in which bearings are forced by the generated commands. Figures A-7 and A-8 provide such graphs for speed ratios of 1:2 and 1:1.

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*The variables used include crossing angle, miss distance, the product of range and rate, the hemisphere (right or left) in which the threat is located, the times to path crossing and the derivatives of miss distance with heading.

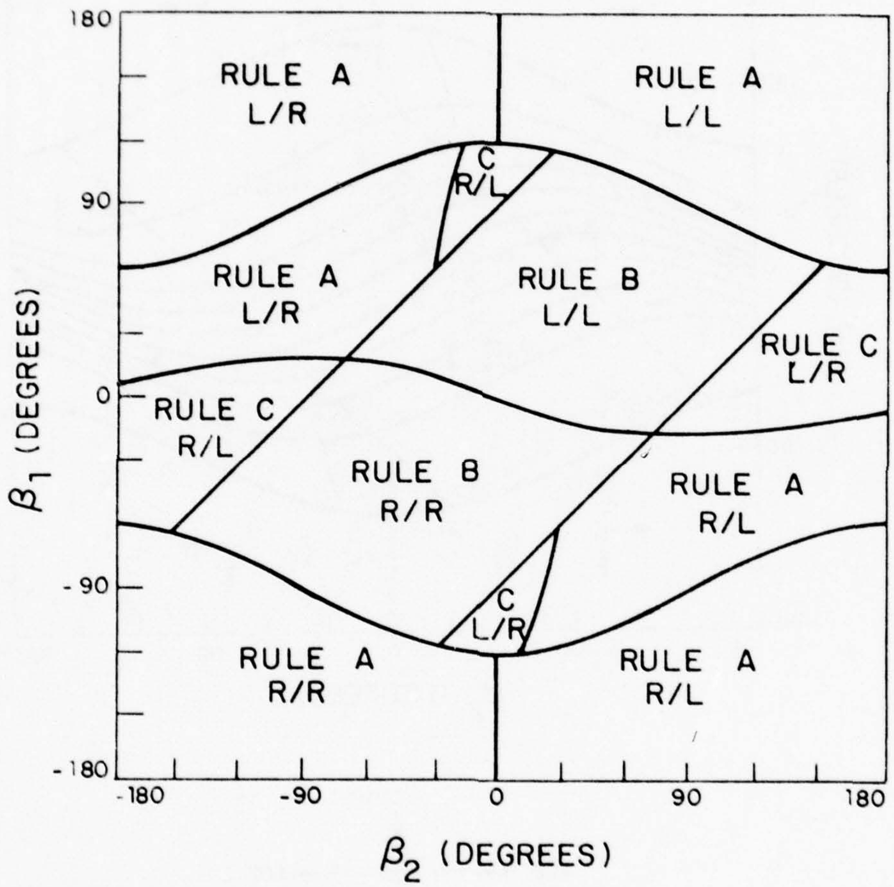

Fig. A-6. Decision map of IPC horizontal command selection logic.

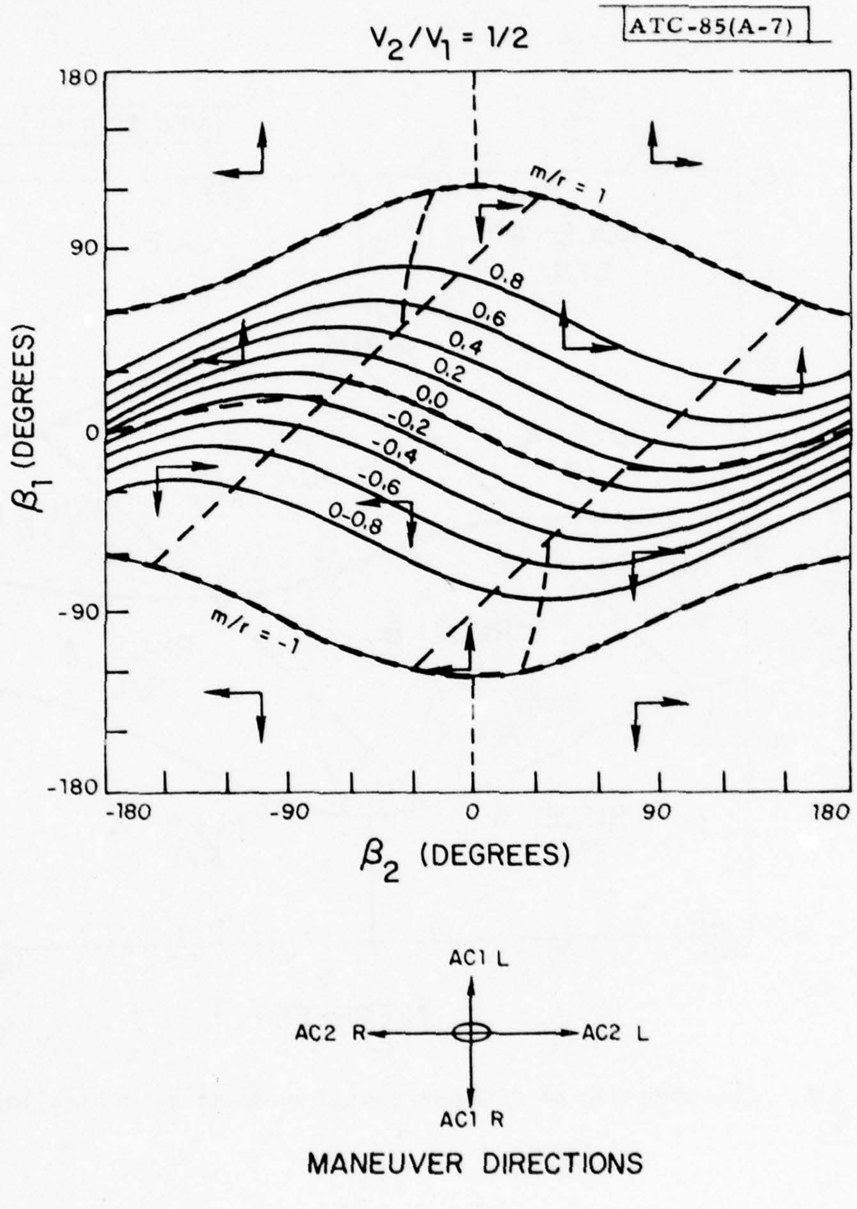

Fig.A-7. Decision map of IPC horizontal command selection logic for 1:2 speed ratio.

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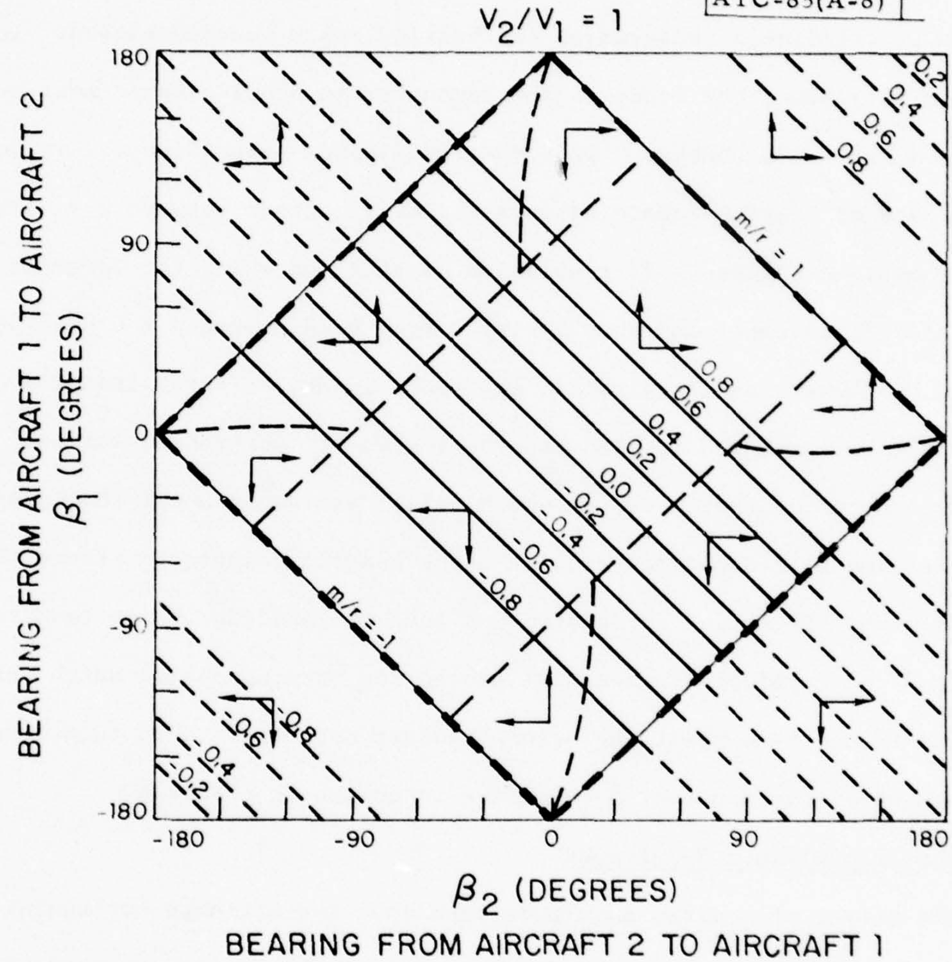

Fig.A-8. Decision map of IPC horizontal command selection logic for 1:1 speed ratio.

A.3 APPLICATION OF RELATIVE MOTION ANALYSIS TO IPC HORIZONTAL AVOIDANCE LOGIC

Statement of Control System Objectives

The control actions required to assure safe separation between aircraft can now be formulated in terms of the bearing space representation. In order to avoid collision, the locus of the encounter in bearing space must be forced away from the $\mu = 0$ contour. If a desired minimum separation, s, is defined, then a band of bearings centered upon the zero contour between $\mu = -s/r$ and $\mu = s/r$ must be avoided. If resolution is effected while the range is large, the ratio s/r is small and only a very narrow band around $\mu = 0$ must be avoided. However, as the aircraft approach closer, a larger fraction of range must be converted to miss and the region of "forbidden bearings" grows. It should be noted that a system which delays avoidance until the latest possible time will sometimes require large heading changes to effect the desired miss. If action is delayed too long the heading change required to escape the forbidden region will exceed the heading change which can be effected in the time remaining before closest approach. When this occurs achievement of the separation objective is no longer possible.

Detrimental Turn Magnitudes

The effect of a given magnitude turn upon the ultimate horizontal separation at closest approach is a function of all five state variables. If the objective of the turn is to increase the magnitude of the miss distance* then it is convenient to define the maneuver effectiveness at a given locus as the magnitude of the derivative of miss distance with respect to heading.

*This is the strategy upon which IPC command selection Rule B is based.

In terms of the miss distance contours, the effectiveness is related to the distance between contours along the bearing axis of the aircraft of interest. For equal speed aircraft (Fig. A-8), the contours are straight lines of 45^{o} slope and thus the maneuver effectiveness is the same for both aircraft at all bearings. However, for a 1:2 speed ratio (Fig. A-7) the contours are flattened in the β_1 dimension. Because of this the maneuver effectiveness for the slower aircraft is less than that of the faster. In fact the effectiveness of maneuvers by the slower aircraft is at best 1/2 that of the faster (i.e., equal to the speed ratio). At worse the effectiveness for the slower is zero (see distance discussion below). The slower aircraft is thus somewhat at the mercy of the faster in that any avoidance maneuver which he undertakes can be cancelled by smaller heading changes of the faster. In the IPC context this fact is most significant when a slower aircraft is attempting to avoid a faster uncommanded (IFR or ATCRBS) aircraft. Such cancellation is evident in Example 10 of Appendix C.

The effectiveness varies with the bearing locus. At those loci for which the miss distance contours are parallel to the β_2 axis, the maneuver effectiveness is zero. These loci are stationary points for miss distance with respect to β_2 and correspond to headings of either local maximum or local minimum miss. The existence of headings of maximum miss has significant implications for collision avoidance. If an aircraft is flying at a heading of maximum miss then any perturbation of its heading will decrease miss.

Furthermore, if the magnitude of avoidance maneuvers are not well controlled, a maneuver which is initially beneficial may overshoot the optimum miss heading and result in decreased miss.

When the slower aircraft is within 30^o of nose-on with respect to the faster aircraft ($-30^o < \beta_1 < 30^o$) there are two values of β for which the miss distance is zero. For loci located near the concave side of the $\mu = 0$ contour, the collision headings bracket the encounter locus in a way that severely restricts the miss distance which can be achieved without crossing the $\mu = 0$ contour. Crossing this contour is undesirable due to the possibility of deterimental results (see 4.4.1) and recovery hazards (see 4.4.4).

Another point which is closely related to those above is that the slower aircraft is often limited in the fraction of the current range which can be converted to miss. This can be deduced from the miss distance contours by noting that for $-60^o < \beta_1 < 60^o$ perturbation of β_2 alone cannot displace the locus through the $\mu = \pm 1$ contours. In fact, if $\beta_1 = 0$, the maximum possible μ value is less than 0.5. On the other hand, the faster aircraft can reach $\mu = \pm 1$ regardless of the value of β_2.

Rule A Strategy

Command selection Rule A attempts to decrease the closure rate to zero by turning each aircraft away from the other. In many situations there is no turn which simultaneously decreases closure rate and increases miss distance (see Fig. A-9 for example). Then the goal of command selection Rule B (increasing projected miss distance) must be opposed in attempting to apply

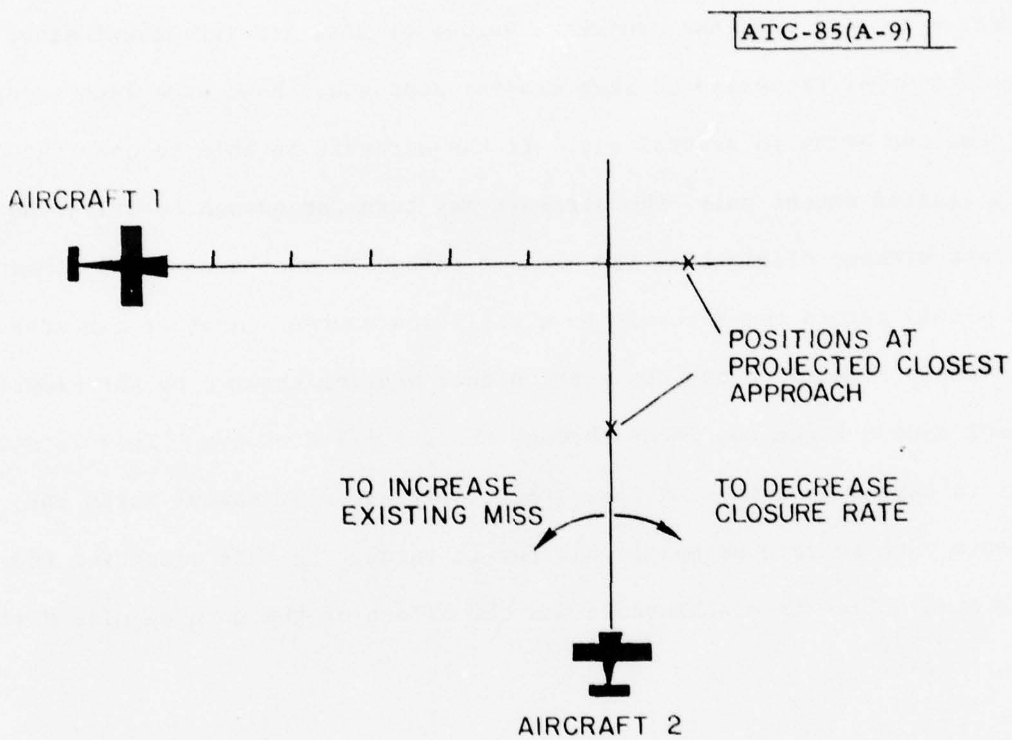

Fig. A-9. Encounter in which turn by aircraft 2 to decrease closure rate reduces existing miss distance.

Rule A. Figure A-10 indicates the regions in which the IPC algorithm issues Rule A commands for which at least one aircraft is turned in a way that decreases the existing miss distance. This opposition may be acceptable if the range rate can be decreased to zero while an acceptable separation still exists - in that case the projected values of miss are irrelevant since the aircraft never proceeded to that closest approach. However a less acceptable outcome can arise in several way. If the aircraft is able to obey the command to a limited extent only* the aircraft may turn far enough to drive the miss to zero without eliminating the closure rate. In such a case the command has merely turned the aircraft to a collision course. Another consideration is closely related to the observation that bearing changes by the slower cannot always force the locus through the $\mu = \pm 1$ contours. This is equivalent to saying that in such cases the slower aircraft cannot force the closure rate to zero no matter how far it turns. In this situation the Rule A objective is unachievable and the effect of the turn on miss distance is critical.

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*The IPC concept requires that pilots obey commands to the extent practicable if their freedom is limited by factors such as clouds, etc. (see Section 2.1).

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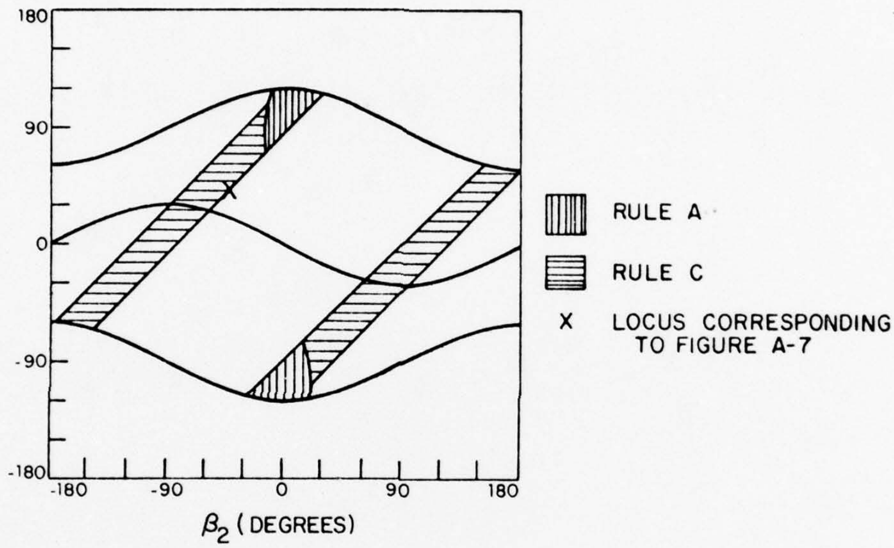

Fig.A-10. Regions in which IPC algorithm commands at least one aircraft to turn in direction which reduces existing miss.

APPENDIX B

PILOT REPLIES TO POST-FLIGHT QUESTIONNAIRES

At the conclusion of the mission debriefing session each subject pilot was asked to complete a questionnaire summarizing his overall impression of the IPC system.

Pilot responses to questions asked on these questionnaires are tabulated below. Forty-five completed questionnaires were available for analysis. No answers were suggested to pilots - only a blank space was left for their reply. Thus the absence of a particular comment need not imply that a pilot would not agree with it, but may mean that the particular comment simply did not occur to him. If a pilot listed more than one item each reply is tabulated.

1. QUESTION: What feature did you like best about the IPC system?

   a. PWI - 18 pilots

   b. Commands when traffic unseen - 6 pilots

   c. Levels of urgency (OPWI, FPWI, commands) - 4 pilots

   d. Threat altitude information inherent in above/below/co-altitude PWI lights - 3 pilots

   e. Aural alarm - 3 pilots

   f. Simplicity - 3 pilots

   g. Commands - 3 pilots

   h. Operational benefits - 2 pilots

   i. Horizontal commands - 1 pilot

j. Negative commands - 1 pilot

k. Unobtrusive when not needed - 1 pilot

l. Display location in cockpit - 1 pilot

The positive response to PWI is striking (21 responses under a and d). It should be noted that of the 9 responses which favorably mentioned positive commands (b and g), 6 were specifically qualified with the condition "when traffic unseen".

2. QUESTION: What features did you like least about the IPC system?

a. Pilot acknowledgement - 8 pilots

b. Not reliable in all situations (e.g., against non-Mode C, multiple aircraft) - 7 pilots

c. Ground assumes control of aircraft - 5 pilots

d. Unnecessary commands - 4 pilots

e. Insufficient PWI information - 4 pilots

f. Display brightness not proper - 4 pilots

g. Commands when visual separation possible - 3 pilots

h. Encourages pilot laxity and decreased vigilance - 3 pilots

i. Commands on too long - 3 pilots

j. Commands force pilot to lose sight of traffic - 2 pilots

k. Insufficient aural alarm - 2 pilots

l. Obtrusive aural alarm - 2 pilots

m. Insufficient PWI warning time - 2 pilots

n. Multiple commands - 1 pilot

o. Difficulty in course recovery - 1 pilot

p. Abruptness - 1 pilot

q. Commands too early - 1 pilot

r. PWI lag - 1 pilot

s. Multiple commands - 1 pilot

t. Anticipated cost of avionics - 1 pilot

u. DABS light on display was disturbing - 1 pilot

v. Searching for PWI traffic approaching from rear - 1 pilot

w. Difficulty of distinguishing three PWI lights in same sector - 1 pilot

The annoyance level of the pilot acknowledgement feature is reflected in the 8 responses which mentioned this feature. Pilot resistance to commands when visual avoidance in adequate is a major factor in the 14 responses under c, d, g, and j.

3. QUESTION: What improvement, if any, would you recommend be made to the IPC system?

a. Change acknowledgement feature - 18 pilots

b. Shield display from sun - 14 pilots

c. Provide range of threat - 9 pilots

d. Provide track of threat - 9 pilots

e. Reduce ambiguity of co-altitude PWI - 6 pilots

f. Make commands optional after visual acquisition - 6 pilots

g. Make the 3 PWI lights in sector more distinguishable - 5 pilots

h. Provide rate of closure - 5 pilots

i. Eliminate red "X" accompanying positive command - 5 pilots

j. Provide manual control over audio alarm volume and/or display brightness - 5 pilots

k. Redesign display - 4 pilots

l. Provide read-out of relative bearing - 3 pilots

m. Change display location on instrument panel - 3 pilots

n. Eliminate premature commands - 2 pilots

o. Provide information on threat's equipment - 2 pilots

p. Reduce system lag - 2 pilots

q. Consider VFR rules of the road in selecting commands - 2 pilots

r. Make system less conservative - 1 pilot

s. Relocate "yes" button - 1 pilot

t. Make negative commands less conservative - 1 pilot

u. Provide more time for pilot to resolve before commands - 1 pilot

v. Provide more information on threat - 1 pilot

w. Provide information on threat speed - 1 pilot

Given the pilot's limited knowledge of the design of the IPC system, it is not surprising that many suggestions for improvements concerned minor details of the display hardware (e.g., "shield display from sun"). The desire for more information on the threat is evident in 36 responses (c,d,e,h,l,o,v, and w).

APPENDIX C

FLIGHT-TEST ENCOUNTER EXAMPLES

Appendix C contains data from actual flight test encounters which serve as examples of particular phenomena discussed in the text. This Appendix should not be viewed as a statistically balanced sample of the flight test data base. In particular, since examples were usually chosen to illustrate algorithm defects which this report recommends be corrected, they contain a disproportionate number of resolution failures. In many cases in which numerous examples of a particular phenomena exist, only a single example which most clearly indicates the issue at hand was selected for inclusion here. In some cases an encounter was included because it illustrated more than one point.

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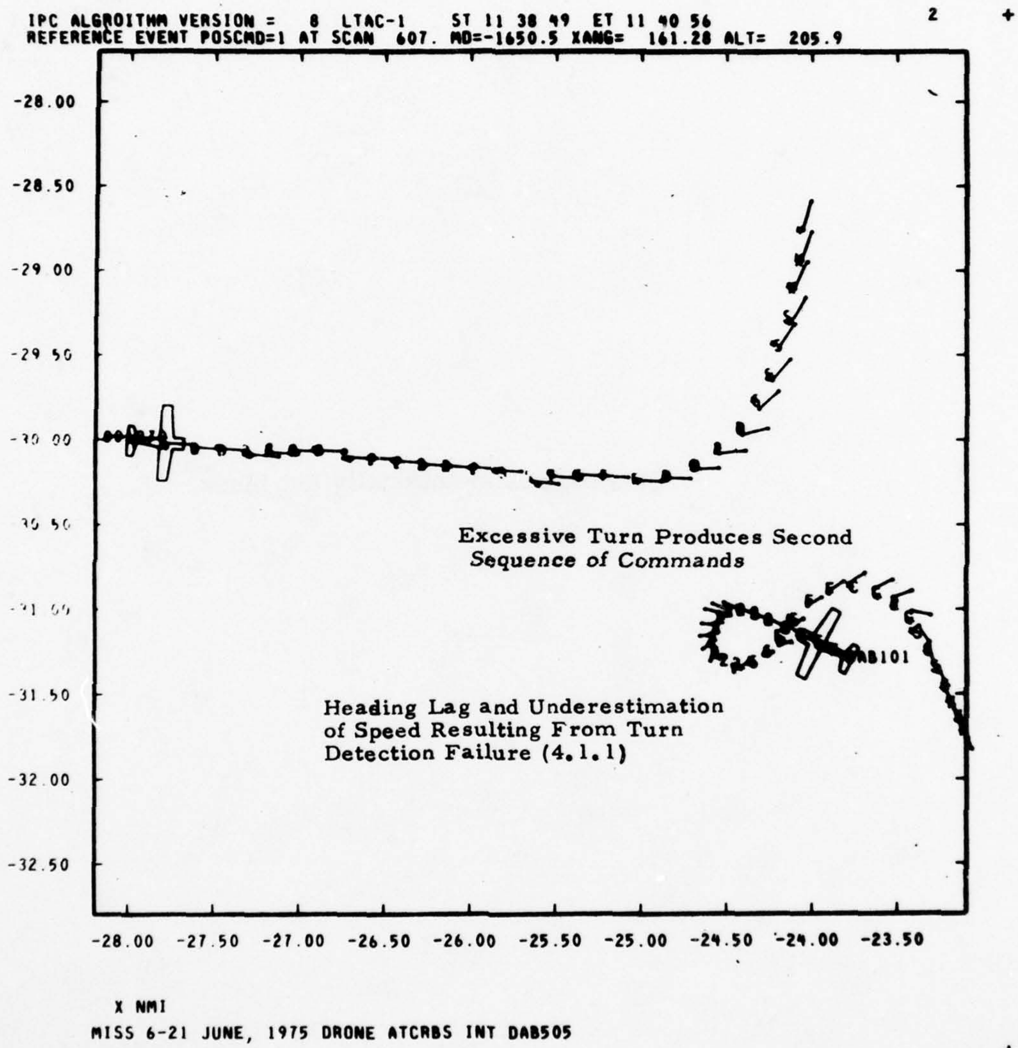
TABLE C-1

EXPLANATION OF ENCOUNTER PLOT SYMBOLOGY

ENCOUNTER RECORDS		ENCOUNTER PLOT SYMBOLS		ENCOUNTER PERFORMANCE		SCAN BY SCAN HISTORY	
Term	Description	Symbol	Meaning	Parameter	Meaning	Column	Data
REF	Referenced event for following parameters*	Solid Line	Track Orientation with 4 Sec Prediction	PRES	Primary Resolution Plane: 1=Hor., 2=Vert.	SCAN	Scan No.
SCAN	Scan No.	Asterisk	Target Report	CPAH, CPAV	(disregard)	AC1	Display State for A/C 1
XANG	Crossing Angle (Deg.)	Aircraft	Orientation at Time of Positive Commands	SCPA	Closest Approach (Ft.)	AC2	Display State for A/C 2
MD	Projected Hor. Miss (Ft.)	X	No Messages	SCPAH	Hor. Sep. at SCPA (Ft.)	POS	Value of POSCMD
ALT	Alt. Separation (Ft.)	S	Steady PWI Only	SCPAV	Vert. Sep. at SCPA (Ft.)	TH	Horizontal Tau (Sec.)
VMD	Proj. Vert. Miss (Ft.)	F	Flashing PWI Only			RANGE	Separation (Ft.)
V	Ground Speed (Kts.)	N	Negative Commands Only			MD	Projected Miss (Ft.)
S&L TURN CD	Type of Approach = Straight & Level Turning Climb or Descend	R,L,C,D	Initial Positive Command Direction			TV	Vertical Tau (Sec.)
		2	Nonresponding Commands			RZ	Alt. Sep. (Ft.)
		3	Horizontal Command Recomputed			VZ	Alt. Sep. (Ft.)
		4	Both A/C Acknowledge			VMD	Vertical Miss Distance (Ft.)
						DOT	Range X Range Rate
						TCMD	Tau Threshold for Commands (Sec.)
						NAC	Number of Aircraft in Conflict

*Parameters estimated from post flight smoothing.

EXAMPLE 1
ENCOUNTER 6-21-15



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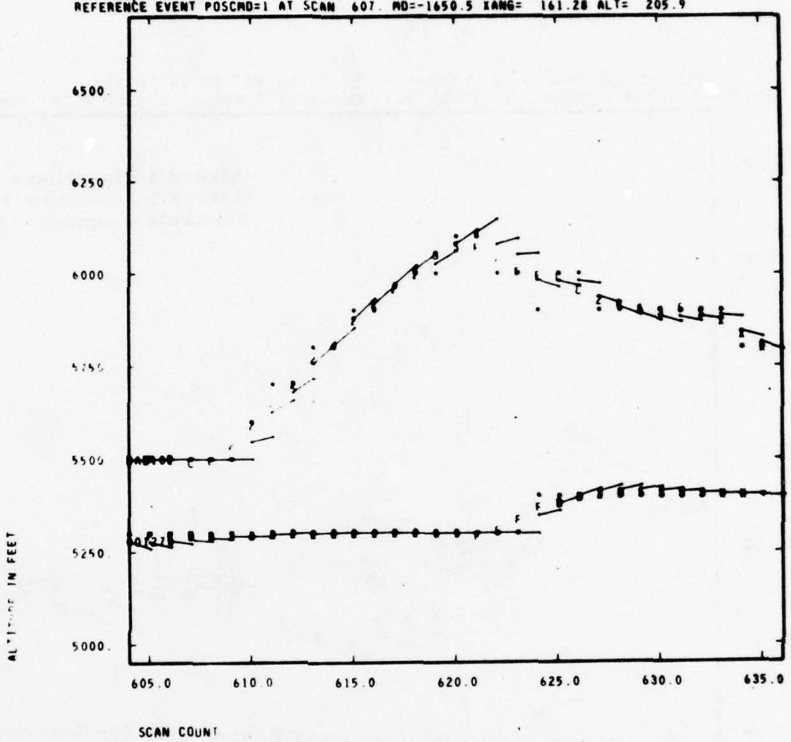
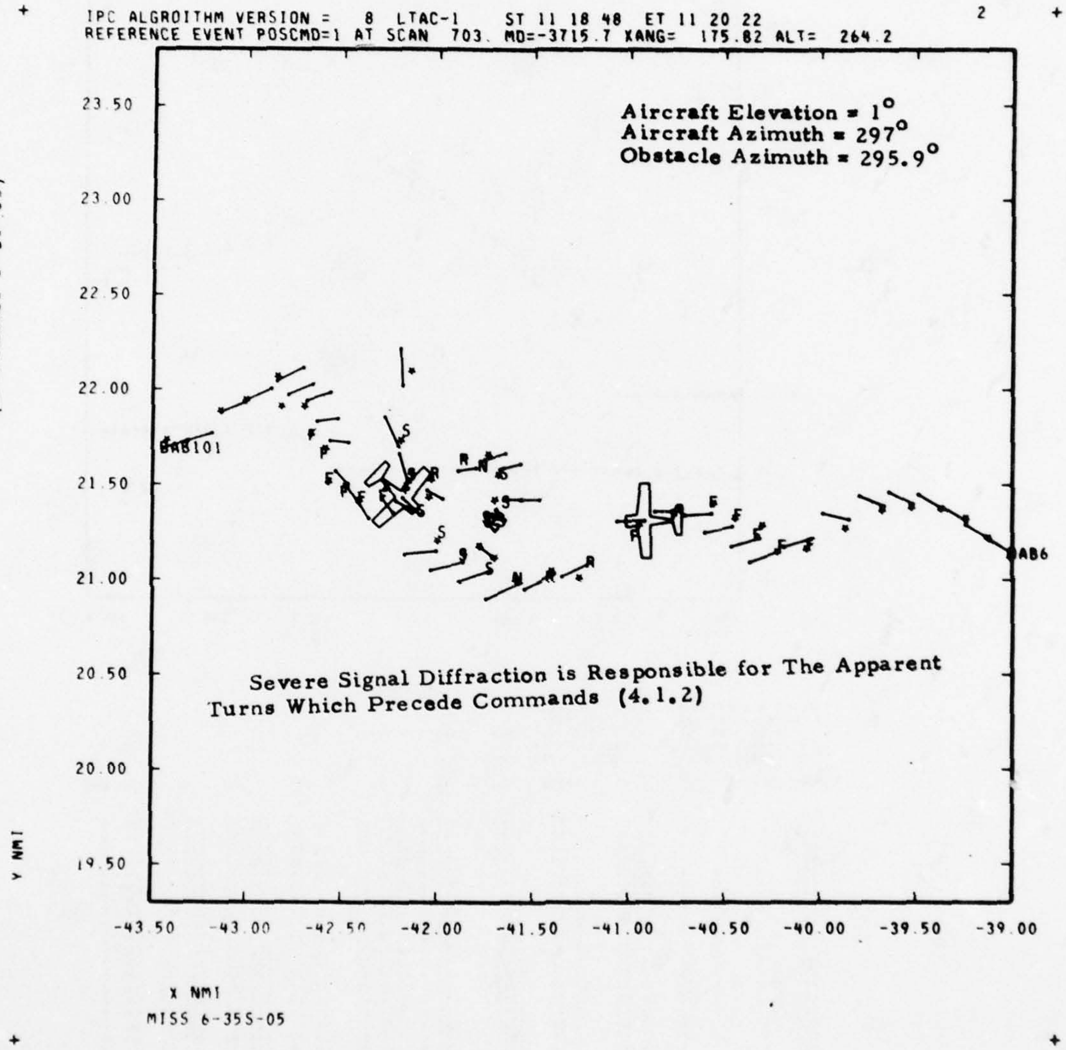
IPC ALGORITHM VERSION = 8 LTAC-1 ST 11 38 49 ET 11 40 56
REFERENCE EVENT POSCMD=1 AT SCAN 607. MD=-1650.5 XANG= 161.28 ALT= 205.9



I C ALGORITHM VER ION = 8 LTAC-1
C AH = 7787.133 V = 196.812
A ON SCAN 625 CPA = 7810.996 SCPAH = 7787.133 SCPAV = 610.1
AC TRACK = 1 DAB101 IFR
AC TRACK = 67 001270 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	D	CMD	NAC
604			0	70.50	4.85	2943.	-33.1	-212.62	-6.41	212.62	-1185.04	64.	0
605	F	F	0	64.35	4.55	2191.	-43.8	-220.82	-5.05	220.82	-1136.58	64.	0
606	F	F	-2	59.45	4.26	1646.	-62.0	-222.21	-3.59	222.21	-1076.73	64.	2
607	F	F	1	56.00	4.00	1490.	-96.1	-219.77	-2.29	219.77	-1003.49	64.	2
608	C	D	1	51.79	3.71	1293.	-171.0	-215.61	-1.26	215.61	-932.02	64.	2
609	C	D	2	49.37	3.47	1472.	-399.0	-211.13	-0.53	211.13	-852.11	64.	2
610	L C	L D	2	45.34	3.19	1306.	-3408.6	-207.12	-0.06	207.12	-778.8	64.	2
611	L C	L D	2	44.28	2.98	1786.	-71.0	-253.77	-3.57	253.77	-697	64.	2
612	L C	L D	2	42.81	2.77	2264.	-41.1	-328.40	-7.98	328.40	-619	64.	2
613	L C	L D	2	42.17	2.58	3069.	-40.6	-379.10	-9.33	379.10	-543.4	64.	2
614	L C	L D	2	39.96	2.36	3648.	-37.1	-455.56	-12.27	455.56	-476.7	64.	2
615	L C	L D	2	41.56	2.23	5005.	-41.7	-503.01	-12.07	503.01	-407.38	64.	2
616	L C	L D	2	44.44	2.11	6166.	-41.8	-574.47	-13.75	574.47	-340.76	64.	2
617	L C	L D	2	47.97	2.00	7067.	-48.7	-616.46	-12.67	616.46	-280.88	64.	2
618	L C	L D	2	54.46	1.92	7818.	-52.6	-669.61	-12.74	669.61	-226.78	64.	2
619	L C	L D	0	79.72	1.91	8855.	-62.8	-708.33	-11.27	708.33	-154.67	64.	0
620	S	S	0	90.68	1.85	7129.	-83.4	-725.91	-8.71	725.91	-126.44	64.	0
621	S	S	-2	61.97	1.70	2821.	-77.4	-779.33	-10.07	779.33	-152.10	64.	2
622	F	F	0	75.12	1.66	2723.	-86.8	-811.00	-9.35	811.00	-119.30	64.	2
623	S	S	0	64.97	1.53	462.	-191.0	-779.93	-4.08	779.93	-115.18	64.	0
624	F	F	-2	56.65	1.42	1576.	-1103.4	-751.80	-0.68	751.80	-110.68	64.	2
625	F	F	1	48.12	1.31	2615.	76.8	-636.46	8.29	106.01	-105.66	64.	2
626	C	D	1	45.54	1.25	2708.	71.8	-601.37	8.38	65.12	-97.4	64.	2
627	C	D	2	58.00	1.28	1746.	80.7	-582.39	7.22	120.34	-81	64.	2
628	R C	L D	0	89.13	1.33	2007.	58.2	-528.34	9.08	0.0	-57	64.	2
629	R C	L D	0	0.0	1.44	8588.	0.0	-495.31	0.0	495.31	17.89	64.	0
630	S	S	0	0.0	1.59	7602.	0.0	-478.25	0.0	478.25	181.22	64.	0
631	S	S	0	0.0	1.82	8244.	0.0	-472.25	0.0	472.25	269.59	64.	0
632	S	S	0	0.0	2.10	7337.	0.0	-473.02	0.0	473.02	392.45	64.	0
633	S	S	0	0.0	2.33	7097.	0.0	-477.33	0.0	477.33	481.34	64.	0
634	X	X	0	0.0	2.60	6869.	0.0	-482.90	0.0	482.90	578.52	64.	0
635	X	X	0	0.0	2.86	6573.	0.0	-441.95	0.0	441.95	663.26	64.	0

EXAMPLE 2
(Encounter 6-35-05)



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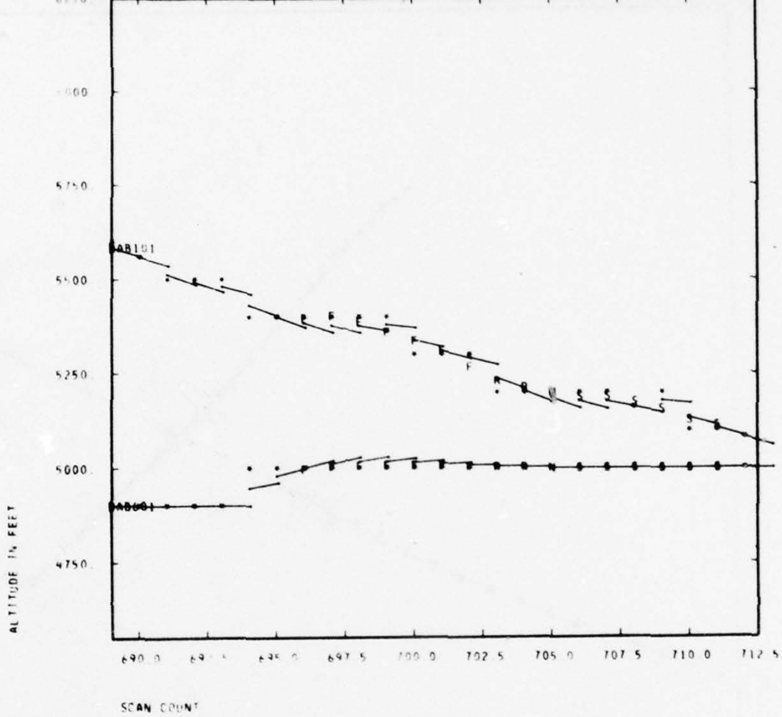
IPC ALGORITHM VERSION = 8 LTAC-1 ST 11 18 48 ET 11 20 22
REFERENCE EVENT POSCMD=1 AT SCAN 703. MD=-3715.7 XANG= 175.82 ALT= 264.2



IPC ALGORITHM VERSION = 8 LTAC-1
CPAH = 1881.053 CPAV = 83.051
CPA ON SCAN 708 SCPA = 1889.068 SCPAH = 1881.053 SCPAV = 173.832
AC1 TRACK = 1 ID = DAB601 VFR
AC2 TRACK = 2 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
69[illegible]			0	44.11	2.91	4640	34.1	422.19	-12.37	26.22	-663.64	32	0
697	F	F	0	43.71	2.66	7262	33.8	384.50	-11.37	20.79	-556.95	32	0
698	F	F	0	39.77	2.42	6147	39.9	366.65	-9.19	72.70	-503.01	32	0
699	F	F	0	39.76	2.24	758	54.0	361.79	-6.70	147.36	-429.37	32	0
700	F	F	0	36.70	2.04	1718	82.8	364.65	-4.41	223.63	-378.25	32	0
701	F	F	0	34.46	1.84	3859	54.0	324.84	-6.02	132.30	-325.25	32	0
702	F	F	-2	27.30	1.57	3045	49.9	299.97	-6.01	107.55	-287.08	32	2
703	F	F	1	19.16	1.27	137[illegible]	55.7	286.64	-5.15	121.99	-250.87	32	2
704	R	R	1	12.18	0.94	2970	31.7	234.97	-7.40	0.0	-166.69	32	2
705	R	R	0	10.86	0.75	4193	26.8	202.31	-7.55	0.0	-69.89	32	2
706	NR	NR	0	0.0	0.68	4097	0.0	184.84	0.0	184.84	22.21	32	0
707	S	S	0	0.0	0.54	3018	0.0	177.84	0.0	177.84	53.53	32	0
708	S	S	0	0.0	0.39	1773	0.0	177.14	0.0	177.14	62.18	32	0
709	S	S	0	0.0	0.52	1391	0.0	162.36	0.0	162.36	109.94	32	0
710	S	S	0	0.0	0.35	50	0.0	179.34	0.0	179.34	70.78	32	0
711	S	S	0	0.0	0.48	1846	0.0	134.32	0.0	134.32	69.40	32	0
712	S	S	0	0.0	0.61	1721	0.0	106.91	0.0	106.91	99.99	32	0

AD-A055 529 MASSACHUSETTS INST OF TECH LEXINGTON LINCOLN LAB F/G 1/4
IPC DESIGN VALIDATION AND FLIGHT TESTING.(U)
MAR 78 J W ANDREWS, J C KOEGLER, K D SENNE F19628-78-C-0002
UNCLASSIFIED ATC-85 FAA-RD-77-150 NL

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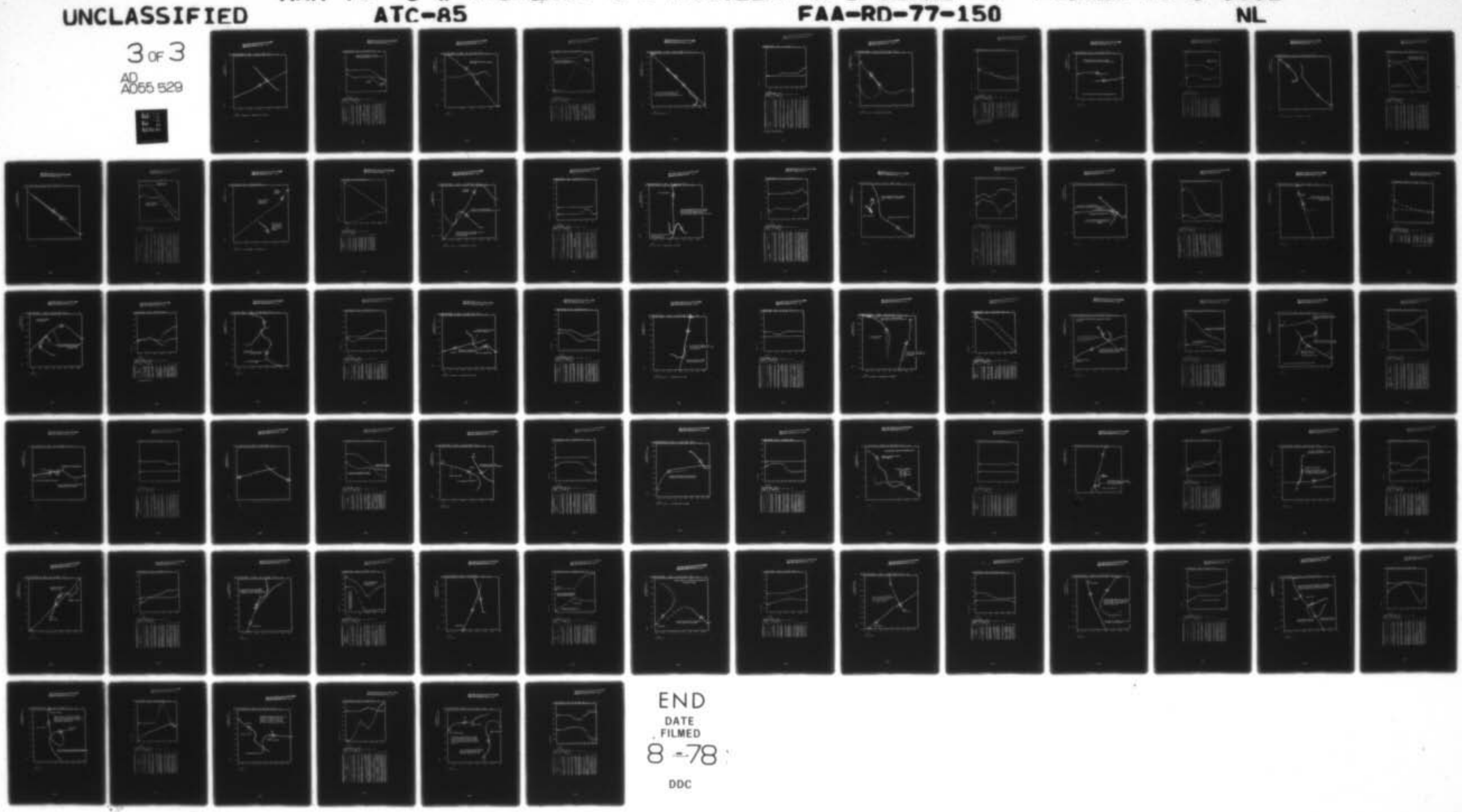

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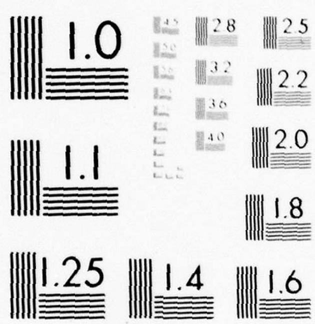

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

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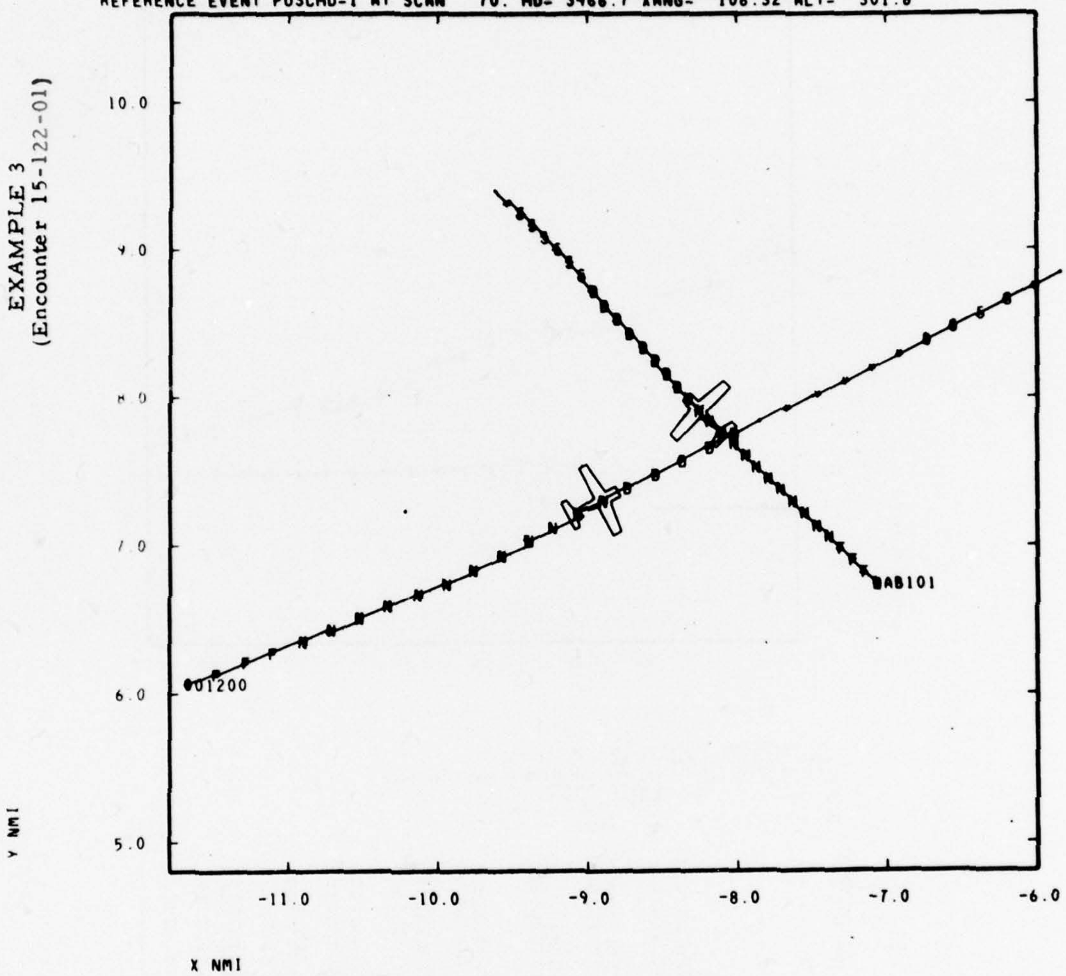
EXAMPLE 3
(Encounter 15-122-01)

IPC ALGROITHM VERSION = 501 LTAC-5 ST 10 1 39 ET 10 3 47 2
REFERENCE EVENT POSCMD=1 AT SCAN 70. MD= 3466.7 XANG= 106.32 ALT= 301.8



MISS 15-122V DECEMBER, 1976 DRONE DAB101 INT ATCRBS

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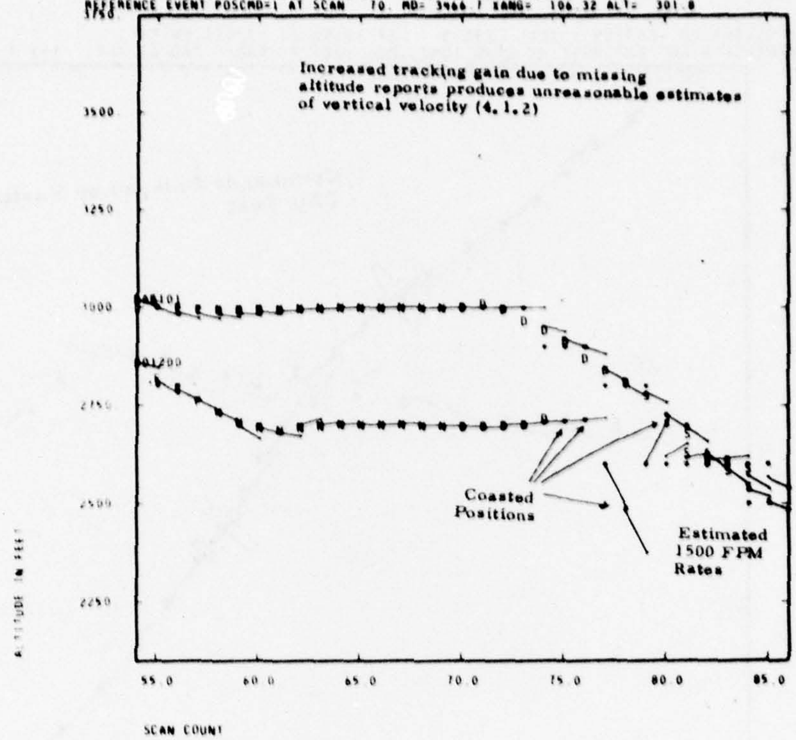
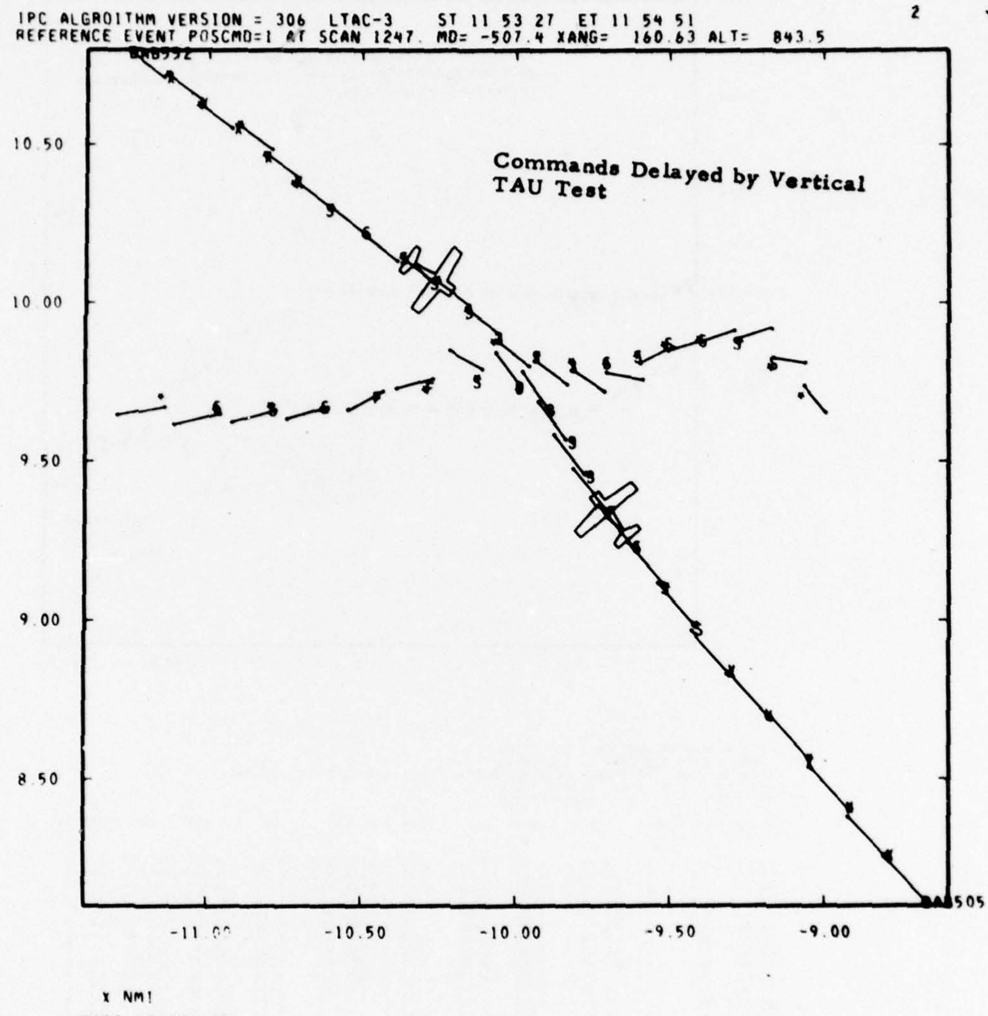
IPC ALGROITHM VERSION = 501 LTAC-5 ST 10 1 39 ET 10 3 47
REFERENCE EVENT POSCMD=1 AT SCAN 70 MD= 3466.7 XANG= 106.32 ALT= 301.8

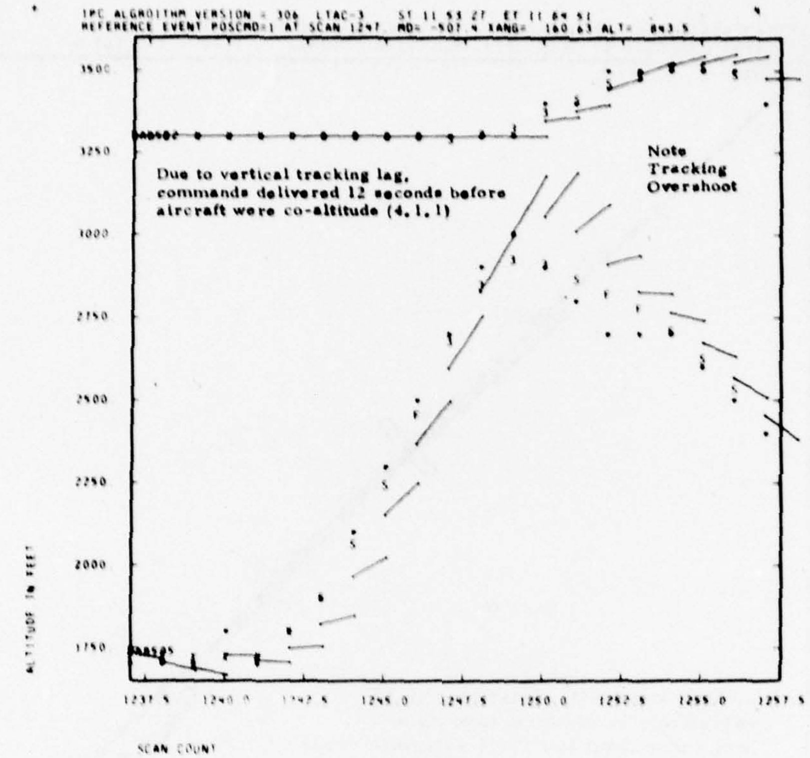


IPC ALGORITHM VERSION = 501 LTAC-5
CPAH = 3624.318 CPAV = 21.090
CPA ON SCAN 72 SCPA = 3636.372 SCPAH = 3624.318 SCPAV = 295.845
AC1 TRACK = 89 ID = 001200 VFR
AC2 TRACK = 2 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
54	X	X	0	74.98	4.94	3741	-3358.0	-178.84	-0.05	178.84	-1152.40	64	0
55	F	F	0	70.19	4.67	3657	122.1	-160.88	1.32	76.52	-1095.59	64	0
56	F	F	0	65.18	4.38	3708	-59.2	-186.88	-3.16	186.88	-1038.60	64	0
57	F	F	-2	61.44	4.12	4060	-77.0	-197.32	-2.56	197.32	-972.74	64	2
58	F	F	0	57.10	3.86	4085	-62.2	-219.99	-3.53	219.99	-910.76	64	2
59	NL	NL	0	53.14	3.59	4168	-55.0	-248.62	-4.52	248.62	-842.98	64	2
60	NL	NL	0	49.98	3.34	4630	-38.9	-286.91	-7.37	286.91	-772.28	64	2
61	NL	NL	0	45.62	3.06	4433	-156.3	-295.95	-1.89	295.95	-706.99	64	2
62	NL	NL	0	41.80	2.80	4432	-131.7	-309.87	-2.35	309.87	-641.02	64	2
63	NL	NL	0	37.39	2.53	4433	72.3	-295.61	4.09	33.86	-576.60	64	2
64	NL	NL	0	33.69	2.28	4523	275.8	-294.84	3.07	226.42	-511.24	64	2
65	NL	NL	0	29.54	2.02	4330	1302.0	-296.73	0.23	282.15	-447.68	64	2
66	NL	NL	0	25.63	1.77	4147	-6286.2	-298.32	-0.05	298.32	-384.97	64	2
67	NL	NL	0	21.81	1.54	3922	-18768.6	-298.09	-0.02	298.09	-324.12	64	2
68	NL	NL	0	17.49	1.30	3831	10658.4	-297.59	0.03	295.81	-263.76	64	2
69	NL	NL	0	13.26	1.08	3517	-773.7	-300.68	-0.39	300.68	-209.46	64	3
70	NL	NL	0	9.65	0.89	3482	-860.4	-301.78	-0.35	301.78	-153.03	64	3
71	NL D	NL D	0	4.94	0.72	3476	-941.5	-302.80	-0.32	302.80	-97.93	64	3
72	NL D	NL D	0	-2.25	0.60	3491	-1008.3	-303.91	-0.30	303.91	-38.41	64	3
73	NL D	NL D	0	7.69	0.59	3554	345.0	-300.19	0.87	244.50	16.45	64	0
74	R D	D	0	-4.01	0.68	3624	338.2	-296.51	0.88	240.39	70.89	64	0
81	R D	S	0	-34.28	2.29	3528	6.4	-110.84	17.40	0.0	507.67	64	0
82	S	S	0	-38.30	2.55	3511	6.8	-79.93	11.85	0.0	572.26	64	0
83	S	S	0	-42.47	2.79	3538	1.7	-20.53	12.07	0.0	627.04	64	0
84	S	S	0	-46.57	3.05	3616	-2.0	23.07	11.61	23.07	685.09	64	0
85	S	S	0	-50.84	3.29	3750	9.5	-36.84	3.88	0.0	739.25	64	0

EXAMPLE 4
(Encounter 13-70-15)





TPC ALGORITHM VERSION = 306 LTAC-3
CPAH = 1045.167 CPAV = 399.451
CPA ON SCAN 1249 SCPA = 1118.899 SCPAH = 1045.167 SCPAV = 399.451
AC1 TRACK = 1 ID = DABS05 VFR
AC2 TRACK = 2 ID = DABS52 IFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
1237	X	X	0	51.64	4.04	1394	-463.7	1515.56	3.27	1515.56	-1113.19	68	0
1238	X	X	0	47.14	3.72	1392	-275.4	1562.15	5.67	1562.15	-1025.99	68	0
1239	X	X	0	42.72	3.39	1518	-259.1	1592.54	6.15	1592.54	-937.53	68	0
1240	X	X	0	38.17	3.07	1185	-291.8	1609.87	5.52	1609.87	-849.27	68	0
1241	X	X	0	33.40	2.73	1177	-1610.9	1571.38	0.98	1571.38	-760.31	68	0
1242	X	X	0	29.04	2.41	1036	-877.1	1586.87	1.81	1586.87	-670.29	68	0
1243	X	X	0	24.73	2.09	880	1099.7	1550.65	-1.42	1454.33	-579.77	68	0
1244	S	S	0	20.18	1.77	764	232.5	1477.55	-6.35	1045.42	-489.23	68	0
1245	S	S	0	15.93	1.47	669	89.5	1334.38	-14.90	320.87	-401.32	68	0
1246	S	S	-2	11.59	1.18	722	47.4	1148.53	-24.17	0.0	-315.73	68	2
1247	F	S	3	6.96	0.90	822	28.7	930.39	-32.45	0.0	-235.06	68	2
1248	L D	L C	3	1.31	0.64	623	18.0	703.71	-39.06	0.0	-160.58	68	2
1249	L D	L C	3	-6.99	0.38	301	10.8	474.47	-43.80	0.0	-93.77	68	2
1250	L D	L C	3	-31.26	0.16	484	6.8	294.38	-43.99	0.0	-33.06	68	2
1251	L D	L C	0	0.0	0.17	903	0.0	291.28	0.0	291.28	19.92	68	0
1252	S	S	0	0.0	0.40	780	0.0	366.27	0.0	366.27	81.40	68	0
1253	F	S	0	0.0	0.67	1115	0.0	533.03	0.0	533.03	138.24	68	0
1254	F	S	0	0.0	0.94	1283	0.0	660.84	0.0	660.84	199.11	68	0
1255	S	S	0	0.0	1.22	734	0.0	749.43	0.0	749.43	276.27	68	0
1256	S	S	0	0.0	1.52	1010	0.0	850.52	0.0	850.52	352.08	68	0
1257	S	S	0	0.0	1.80	476	0.0	958.27	0.0	958.27	414.49	68	0

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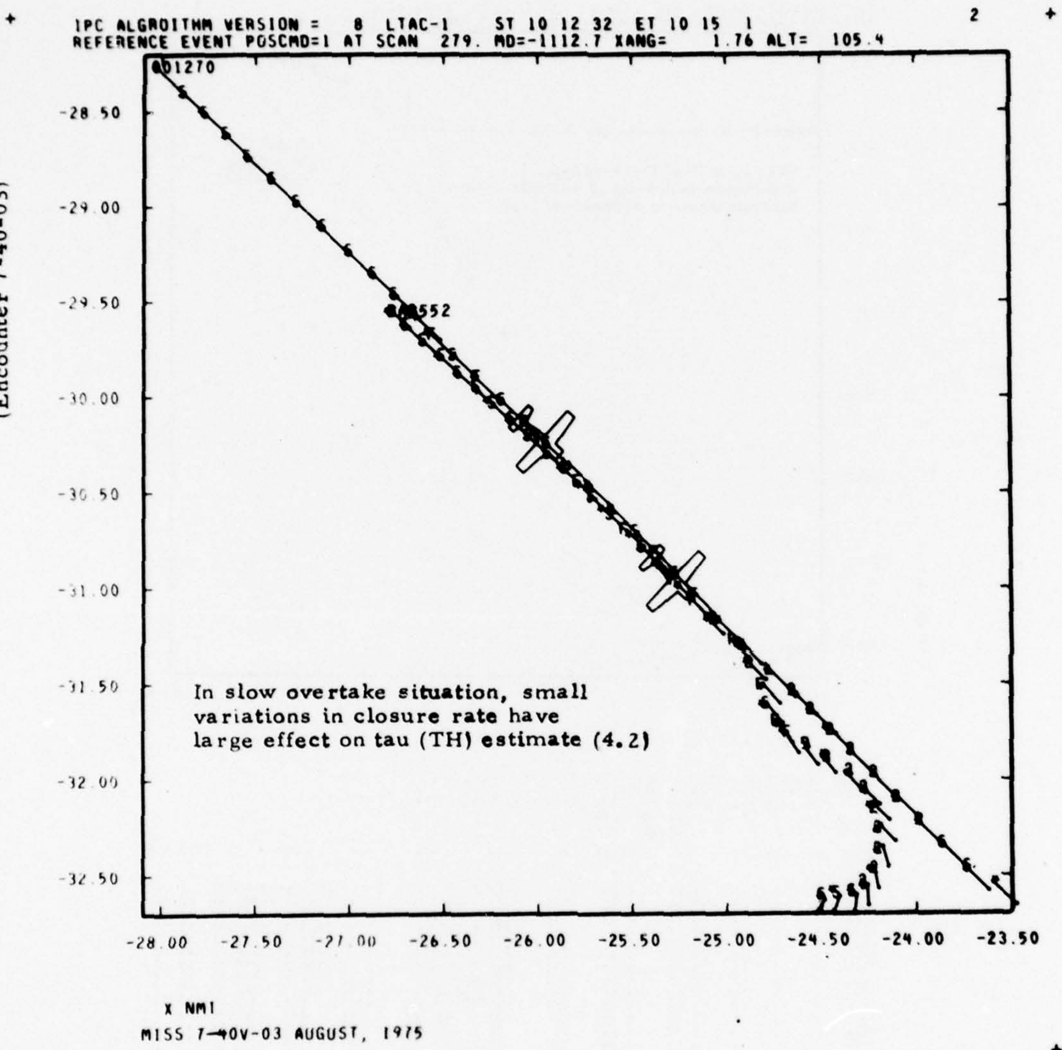
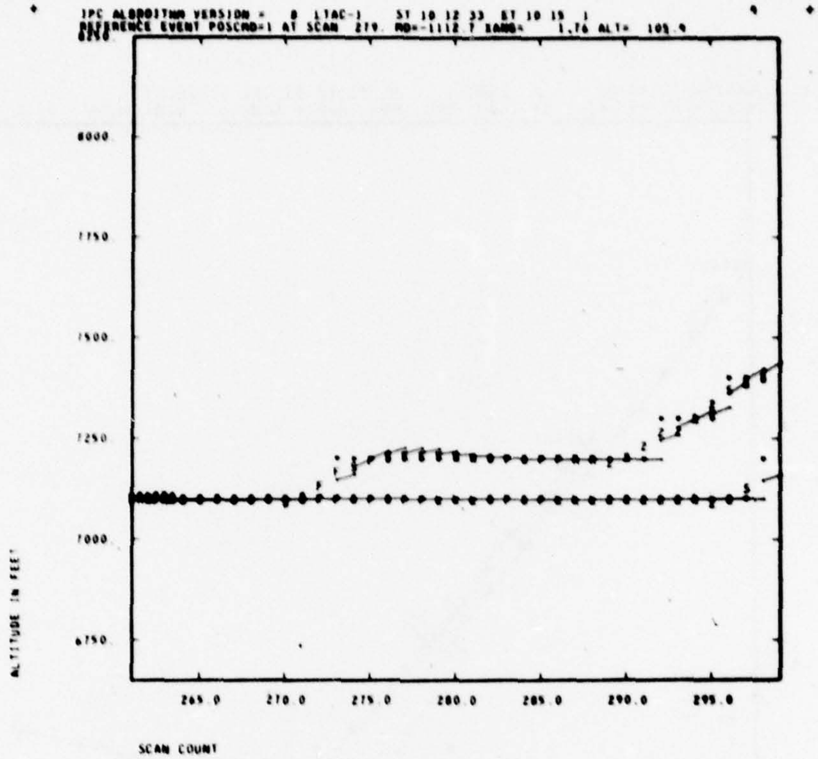
EXAMPLE 5
(Encounter 7-40-03)



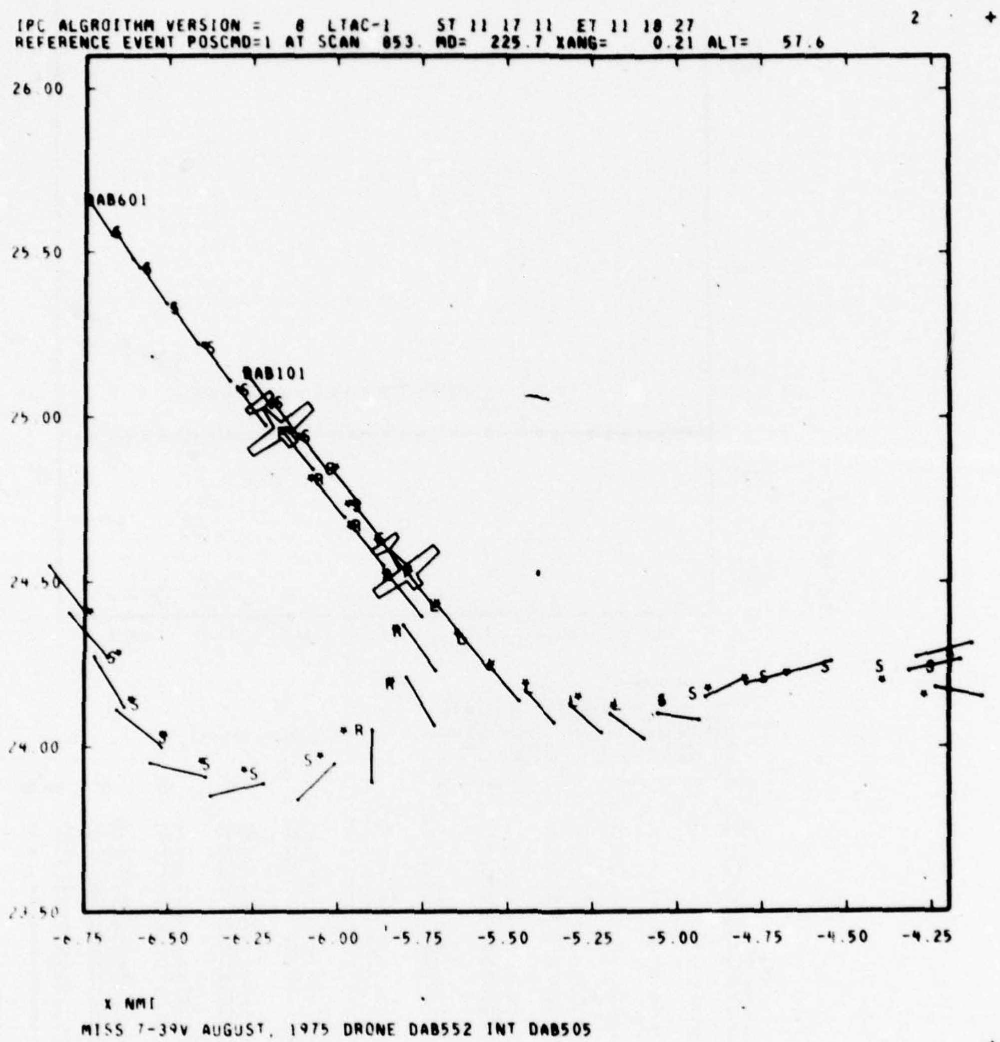


IPC ALGORITHM VERSION = 8 LTAC-1
CPAH = 2397.745 CPAV = 0.0
CPA ON SCAN 294 SCPA = 2406.091 SCPAH = 2397.745 SCPAV = 200.242
AC1 TRACK = 2 ID = DAB552 IFR
AC2 TRACK = 76 ID = 001270 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
261	S	S	0	179.36	1.88	378	65.9	13.55	-0.21	0.29	-63.45	64	0
262	S	S	0	145.65	1.80	249	7.3	6.09	-0.83	0.0	-70.96	64	0
263	S	S	0	111.84	1.71	179	1.6	1.98	-0.93	0.0	-81.69	64	0
264	S	S	0	110.93	1.68	99	-1.9	-1.19	-0.85	1.19	-79.72	64	0
265	S	S	0	101.75	1.62	96	-3.6	-2.99	-0.68	2.99	-79.95	64	0
266	S	S	0	103.58	1.59	309	-5.6	-2.77	-0.50	2.77	-75.08	64	0
267	S	S	0	107.25	1.56	423	-7.8	-2.59	-0.32	2.59	-69.05	64	0
268	S	S	0	89.58	1.46	348	-11.1	-2.05	-0.19	2.05	-71.63	64	0
269	S	S	0	85.63	1.42	468	-17.7	-1.50	-0.08	1.50	-69.28	64	0
270	S	S	0	78.56	1.36	359	-52.8	-0.98	-0.02	0.98	-67.58	64	0
271	S	S	0	77.42	1.32	256	28.8	-0.57	0.02	0.0	-63.39	64	0
272	S	S	0	72.55	1.27	85	7.0	-0.26	0.04	0.0	-60.69	64	0
273	F	F	0	73.12	1.23	37	1.5	-0.06	0.04	0.0	-56.06	64	0
274	F	F	0	81.59	1.21	216	-13.0	-96.39	-3.57	96.39	-49.29	64	0
275	S	S	0	67.98	1.13	22	-15.8	-78.92	-4.98	78.92	-49.97	64	0
276	F	F	0	81.82	1.14	109	-19.8	-99.41	-5.02	99.41	-41.98	64	0
277	S	S	0	71.91	1.07	261	-25.6	-110.90	-4.32	110.90	-40.65	64	0
278	F	F	-2	60.63	1.01	512	-39.6	-119.79	-3.32	119.79	-40.59	64	2
279	F	F	1	62.99	1.00	712	-49.8	-115.05	-2.31	115.05	-36.78	64	2
280	F	L	1	57.99	0.95	848	-78.9	-113.07	-1.99	113.07	-39.84	64	2
281	R	L	1	60.05	0.93	1157	-143.9	-110.12	-0.77	110.12	-31.25	64	2
282	R	L	0	83.62	0.96	1064	-363.3	-107.08	-0.29	107.08	-23.73	64	0
283	S	S	0	65.97	0.89	1352	84593.7	-104.93	0.0	104.35	-23.39	64	0
284	F	F	0	83.93	0.90	2429	641.3	-102.37	0.16	92.15	-18.88	64	0
285	S	S	-2	60.61	0.83	3027	453.9	-100.93	0.22	86.70	-19.97	64	2
286	F	F	1	63.10	0.82	3555	446.9	-100.02	0.22	85.70	-18.29	64	2
287	F	L	1	26.98	0.71	2835	517.8	-99.53	0.19	87.23	-22.59	64	2
288	R	L	1	12.92	0.65	2139	671.5	-99.39	0.15	89.87	-24.71	64	2
289	R	L	2	-9.29	0.55	1228	968.5	-99.33	0.10	92.76	-26.63	64	2
290	R C	L D	2	-14.78	0.50	698	1565.9	-99.42	0.06	95.36	-26.15	64	2
291	R C	L D	2	-16.59	0.50	492	2974.3	-99.56	0.03	97.92	-23.69	64	2
292	R C	L D	2	-22.65	0.46	639	7726.0	-99.70	0.01	98.87	-20.39	64	2
293	R C	L D	2	-33.66	0.42	1252	-90.7	-146.21	-3.59	146.21	-16.70	64	2
294	R C	L D	2	-95.59	0.39	2205	-35.7	-178.88	-5.01	178.88	-6.72	64	2
296	R C	L D	0	0.0	0.43	2205	0.0	-210.56	0.0	210.56	23.18	64	0
297	S	S	0	0.0	0.52	2015	0.0	-261.39	0.0	261.39	96.87	64	0
298	S	S	0	0.0	0.69	1860	0.0	-299.30	0.0	299.30	83.74	64	0

Note alteration of alarm states due to non-monotonic changes in tau (TH).

EXAMPLE 6
(Encounter 7-39-08)



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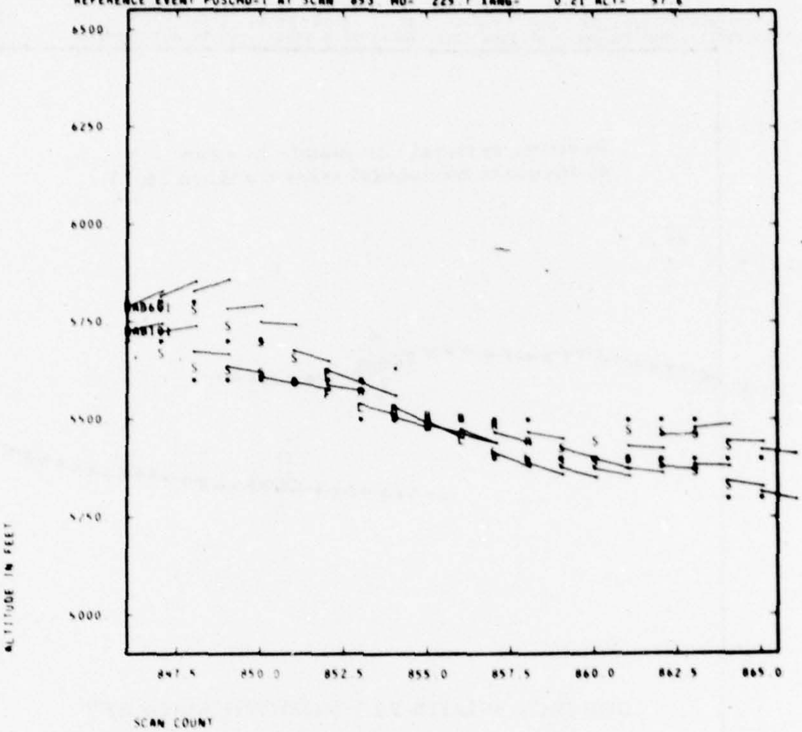
IPC ALGROITHM VERSION = 8 LTAC-1 ST 11 17 11 ET 11 18 27
REFERENCE EVENT POSCMD=1 AT SCAN 853 MD= 225 7 XANG= 0 21 ALT= 57 6

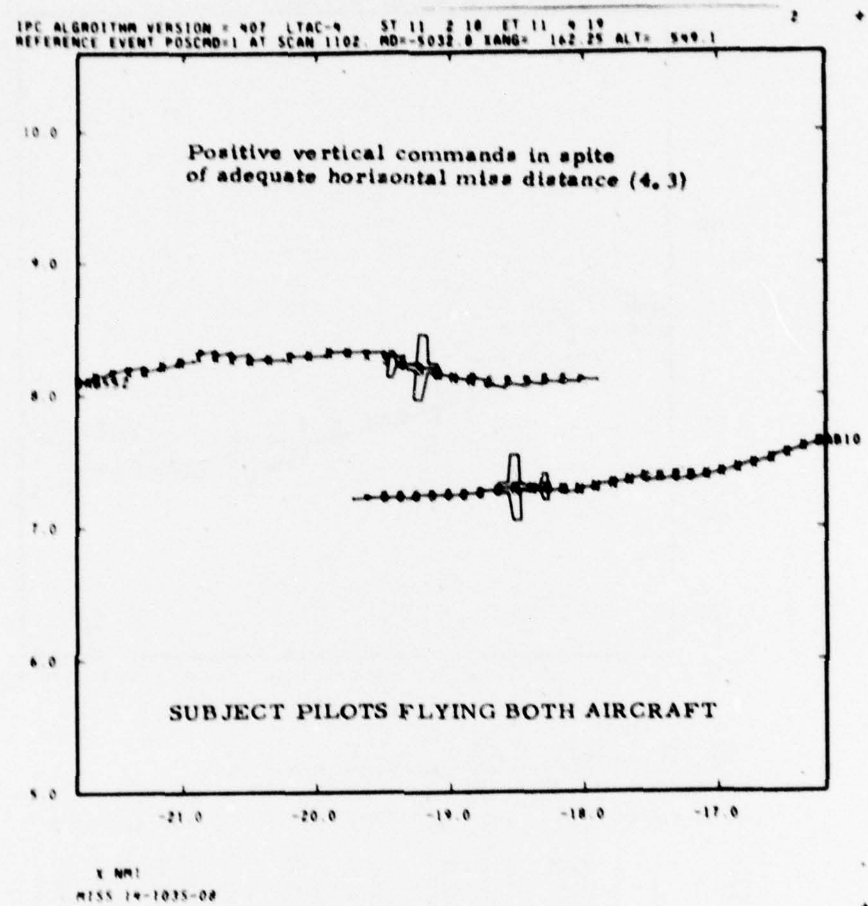


IPC ALGORITHM VERSION = 8 LTAC-1
CPAH = 2518 462 CPAV = 9.000
CPA ON SCAN 855 SCPA = 2518 603 SCPAH = 2518 462 SCPAV = 26 742
AC1 TRACK = 1 ID = DAB601 IFR
AC2 TRACK = 3 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
846	S	S	0	300 26	0 70	3079	-6 7	-18 09	-2 71	18 09	-2 40	64	0
847	S	S	0	578 79	0 70	3982	-11 6	-61 75	-5 34	61 75	-1 27	64	0
848	S	S	0	723 61	0 70	4219	-15 1	-90 66	-5 98	90 66	-1 00	64	0
849	S	S	0	529 64	0 69	3971	-16 7	-153 82	-9 20	153 82	-1 23	64	0
850	S	S	0	338 97	0 68	3940	-25 2	-147 98	-5 88	147 98	-1 72	64	0
851	S	S	0	91 03	0 65	2259	-42 4	-137 98	-3 26	137 98	-4 47	64	0
852	S	S	-2	29 50	0 62	903	35 4	-80 83	2 28	0 0	-7 22	64	2
853	F	F	1	-5 10	0 57	141	7 8	-38 57	4 95	0 0	-10 44	64	2
854	R	L	1	-18 83	0 53	340	28 6	-56 65	1 98	0 0	-12 16	64	2
855	R	L	1	-35 07	0 47	323	7 0	-26 17	3 76	0 0	-14 02	64	2
856	R	L	1	-46 74	0 42	595	1 4	-6 00	4 17	0 0	-14 39	64	2
857	R	L	1	-61 84	0 40	1726	4 4	-11 05	2 50	0 0	-11 83	64	2
858	R	L	1	-426 70	0 49	2993	-22 8	-52 16	-2 29	52 16	-1 00	64	2
859	R	L	0	0 0	0 70	2481	0 0	-78 21	0 0	78 21	66 82	64	0
860	S	S	0	0 0	0 95	1196	0 0	-49 30	0 0	49 30	206 93	64	0
861	S	S	0	0 0	1 32	1144	0 0	-26 71	0 0	26 71	336 73	64	0
862	S	S	0	0 0	1 61	1911	0 0	-57 23	0 0	57 23	413 06	64	0
863	S	S	0	0 0	1 86	4329	0 0	-79 71	0 0	79 71	418 56	64	0
864	S	S	0	0 0	2 33	6474	0 0	-94 76	0 0	94 76	516 09	64	0
865	S	S	0	0 0	2 36	4950	0 0	-103 48	0 0	103 48	565 53	64	0

Due to slow closure tate and the non linear dependence of TH upon range, tau (TH) decreases from 91.0 to -5.1 in 8 seconds of clock time (4.2)

EXAMPLE 7
(Encounter 14-103-08)



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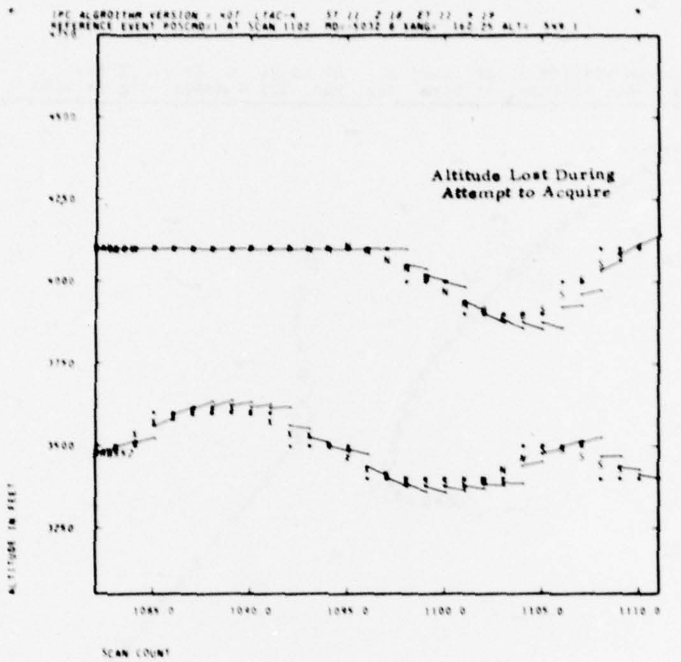

IPC ALGORITHM VERSION = 407 LTAC=4
CPAN = 5227 953 CPAV = 427 123
CPA ON SCAN 1105 SCPA = 5245 951 SCPAN = 5227 953 SCPAV = 436 313
AC1 TRACK = 2 ID = DAB552 IFR
AC2 TRACK = 4 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCND	NAC
1082	3	3	0	105.68	5.77	13692	209.5	654.52	-3.12	442.11	-1126.46	68	0
1083	3	3	0	102.84	5.55	12290	138.7	621.46	-4.48	317.12	-1070.00	68	0
1084	3	3	0	99.17	5.32	11947	131.7	601.37	-4.57	240.76	-1017.45	68	0
1085	3	3	0	94.85	5.08	11654	144.2	540.13	-3.46	321.15	-969.48	68	0
1086	3	3	0	91.01	4.85	11542	64.4	539.13	-6.38	104.44	-920.19	68	0
1087	3	3	0	86.39	4.61	10677	74.8	506.15	-6.77	46.07	-876.30	68	0
1088	3	3	0	81.58	4.37	10449	81.3	457.60	-6.00	74.85	-832.13	68	0
1089	3	3	0	77.25	4.14	10455	101.6	479.47	-4.72	158.54	-785.44	68	0
1090	3	3	0	72.68	3.89	10904	142.4	478.03	-3.36	249.23	-737.23	68	0
1091	3	7	0	68.58	3.67	10016	224.3	480.45	-2.14	334.80	-692.51	68	0
1092	3	7	2	63.73	3.43	9859	410.0	484.56	-3.18	404.20	-649.84	68	2
1093	3	7	0	59.10	3.20	7728	-188.8	535.39	2.84	535.39	-606.76	68	2
1094	3	ND	0	54.09	2.95	6877	-125.1	571.46	4.57	571.46	-561.17	68	2
1095	3	ND	0	49.36	2.71	7056	-122.9	595.58	4.85	595.58	-514.40	68	2
1096	3	ND	0	44.92	2.47	6761	-141.7	608.88	4.30	608.88	-467.18	68	2
1097	3	ND	0	41.54	2.24	7180	-98.7	661.15	5.70	661.15	-411.13	68	2
1098	3	ND	0	38.06	2.01	7198	-98.8	694.70	7.03	694.70	-356.57	68	2
1099	3	ND	0	34.64	1.79	6404	-232.0	667.11	2.88	667.11	-304.44	68	2
1100	5	ND	0	30.89	1.57	6471	-2846.6	692.66	0.23	692.66	-253.56	68	2
1101	5	ND	0	26.68	1.35	5778	510.1	623.39	-1.22	540.28	-208.80	68	2
1102	5	ND	1	21.67	1.15	5371	109.4	563.24	-5.13	219.72	-159.60	68	2
1103	NC	C	1	23.66	1.00	5208	80.3	522.11	-6.50	19.48	-109.08	68	2
1104	NC	C	1	19.24	0.89	5198	78.8	496.77	-6.30	68.33	-59.83	68	2
1105	NC	C	0	181.42	0.88	5363	50.8	437.28	-8.61	0.0	-10.00	68	0
1106	5	5	0	-37.15	0.88	5186	46.4	400.04	-8.61	0.0	49.50	68	0
1107	5	5	0	-25.53	1.01	5350	105.2	426.43	-4.05	150.40	106.46	68	0
1108	5	5	0	-29.97	1.20	5443	444.0	451.15	-1.02	382.06	170.08	68	0
1109	5	5	0	-26.56	1.39	5477	-76.1	564.26	7.41	564.26	226.51	68	0
1110	5	5	0	-24.18	1.60	5424	-59.3	644.40	10.87	644.40	281.84	68	0

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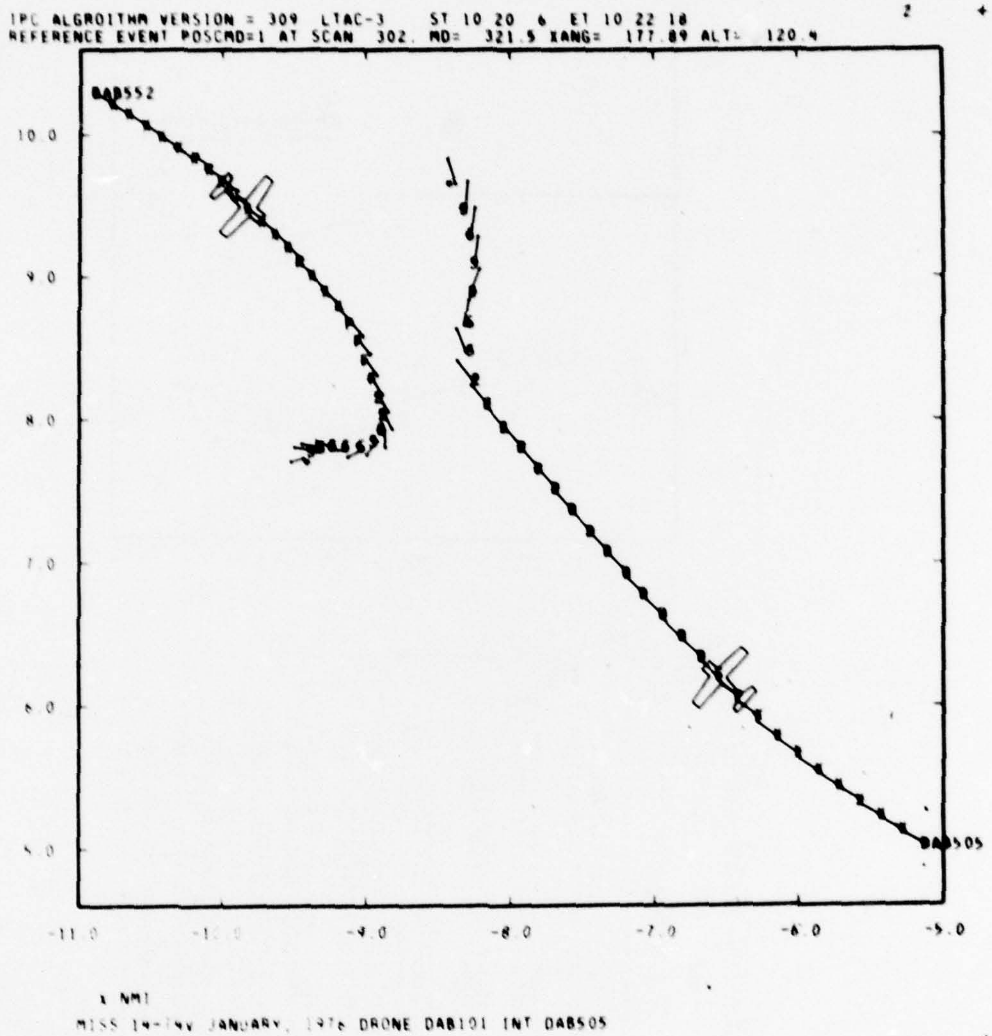
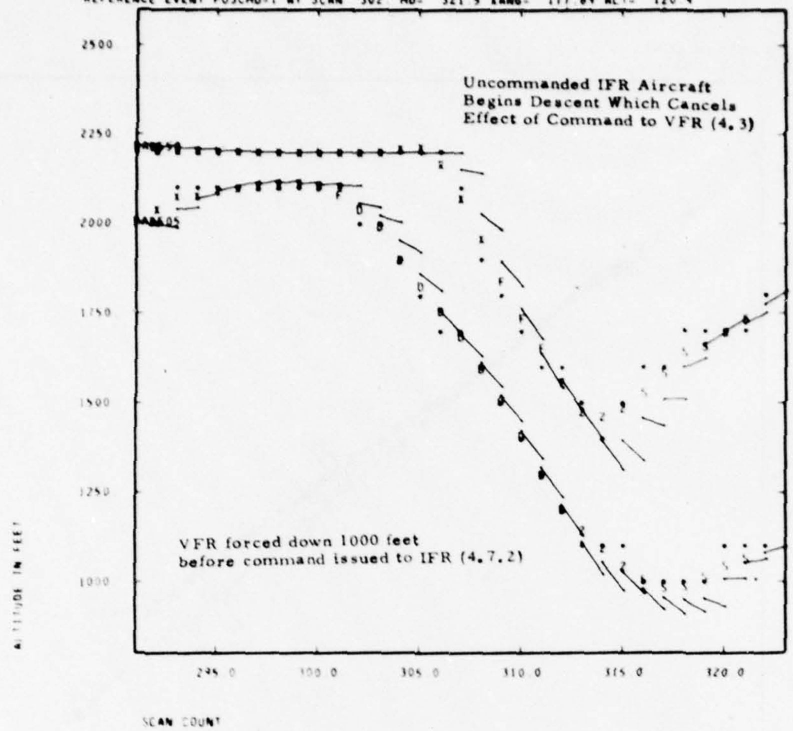
EXAMPLE 8
(Encounter 14-74-04)



IPC ALGORITHM VERSION = 309 LTAC-3 ST 10 20 6 ET 10 22 18
REFERENCE EVENT POSCMD=1 AT SCAN 302 MD= 321.5 XANG= 177.89 ALT= 120.4



IPC ALGORITHM VERSION = 309 LTAC-3
CPAH = 4472.352 CPAV = 85.508
CPA ON SCAN 314 SCPA = 4487.562 SCPAH = 4472.352 SCPAV = 369.205
AC1 TRACK = 1 ID = DAB505 VFR
AC2 TRACK = 2 ID = DAB552 IFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DD1	TCMD	NAC
291	X	X	0	114.70	8.11	10793.	-36.4	194.43	5.35	194.43	-2054.89	68.	0
292	X	X	0	110.08	7.81	9994.	-43.9	209.25	4.76	209.25	-1982.32	68.	0
293	X	X	0	104.86	7.49	9265.	-57.3	215.79	3.76	215.79	-1916.17	68.	0
294	X	X	0	99.83	7.18	8616.	240.7	170.63	-0.71	122.43	-1848.04	68.	0
295	X	X	0	94.66	6.87	7971.	45.4	136.24	-3.00	0.0	-1780.24	68.	0
296	X	X	0	89.71	6.55	7400.	29.7	112.58	-3.79	0.0	-1708.88	68.	0
297	X	X	0	84.79	6.24	6758.	26.7	98.12	-3.67	0.0	-1636.45	68.	0
298	X	X	0	79.89	5.92	6451.	29.4	90.59	-3.08	0.0	-1561.63	68.	0
299	X	X	0	75.49	5.61	5606.	37.9	87.95	-2.32	0.0	-1482.58	68.	0
300	X	X	0	70.79	5.29	4689.	55.8	88.21	-1.58	0.0	-1403.31	68.	0
301	F	X	-2	65.74	4.96	3207.	94.7	90.10	-0.95	25.43	-1327.94	68.	2
302	F	X	1	61.20	4.64	2183.	192.4	92.51	-0.48	59.81	-1246.45	68.	2
303	D	X	1	56.31	4.32	1215.	-43.9	141.29	3.22	141.29	-1166.29	68.	2
304	D	X	1	51.68	3.99	668.	-37.1	175.87	4.75	175.87	-1083.56	68.	2
305	D	X	1	46.96	3.66	138.	-29.6	244.31	8.26	244.31	-999.72	68.	2
306	D	X	1	42.25	3.33	706.	-27.2	335.36	12.35	335.36	-914.50	68.	2
307	D	X	1	37.84	3.01	993.	-27.2	439.88	16.15	439.88	-826.99	68.	2
308	D	X	1	33.34	2.69	1374.	-36.7	458.15	12.47	458.15	-738.10	68.	2
309	D	X	1	28.65	2.36	1676.	-77.9	413.26	5.31	413.26	-648.25	68.	2
310	D	F	1	23.93	2.03	1842.	-521.1	372.71	0.72	372.71	-557.85	68.	2
311	D	F	1	19.54	1.71	2363.	181.6	340.79	-1.88	213.16	-464.78	68.	2
312	D	F	1	15.42	1.41	2871.	106.3	317.59	-2.99	114.35	-370.43	68.	2
313	D	F	2	11.73	1.14	3369.	-1492.8	349.02	0.23	349.02	-275.82	68.	2
314	R D	R C	2	7.82	0.89	3546.	-194.6	373.33	1.92	373.33	-184.73	68.	2
315	R D	R C	2	5.05	0.72	3822.	405.1	343.66	-0.85	285.97	-95.00	68.	2
316	R D	R C	0	-29.16	0.71	4323.	-310.2	367.98	1.19	367.98	16.33	68.	0
317	S	S	0	-9.69	0.88	3650.	-53.8	478.42	8.89	478.42	151.46	68.	0
318	S	S	0	-12.46	1.13	1075.	-47.3	555.17	11.73	555.17	261.83	68.	0
319	S	S	0	-18.59	1.39	1285.	-43.4	649.22	14.97	649.22	301.99	68.	0
320	S	S	0	-29.29	1.62	766.	-48.7	707.05	14.53	707.05	274.06	68.	0
321	S	S	0	-30.30	1.82	450.	-78.2	690.63	8.83	690.63	349.42	68.	0
322	S	S	0	-35.37	2.01	290.	-148.6	668.69	4.50	668.69	372.53	68.	0

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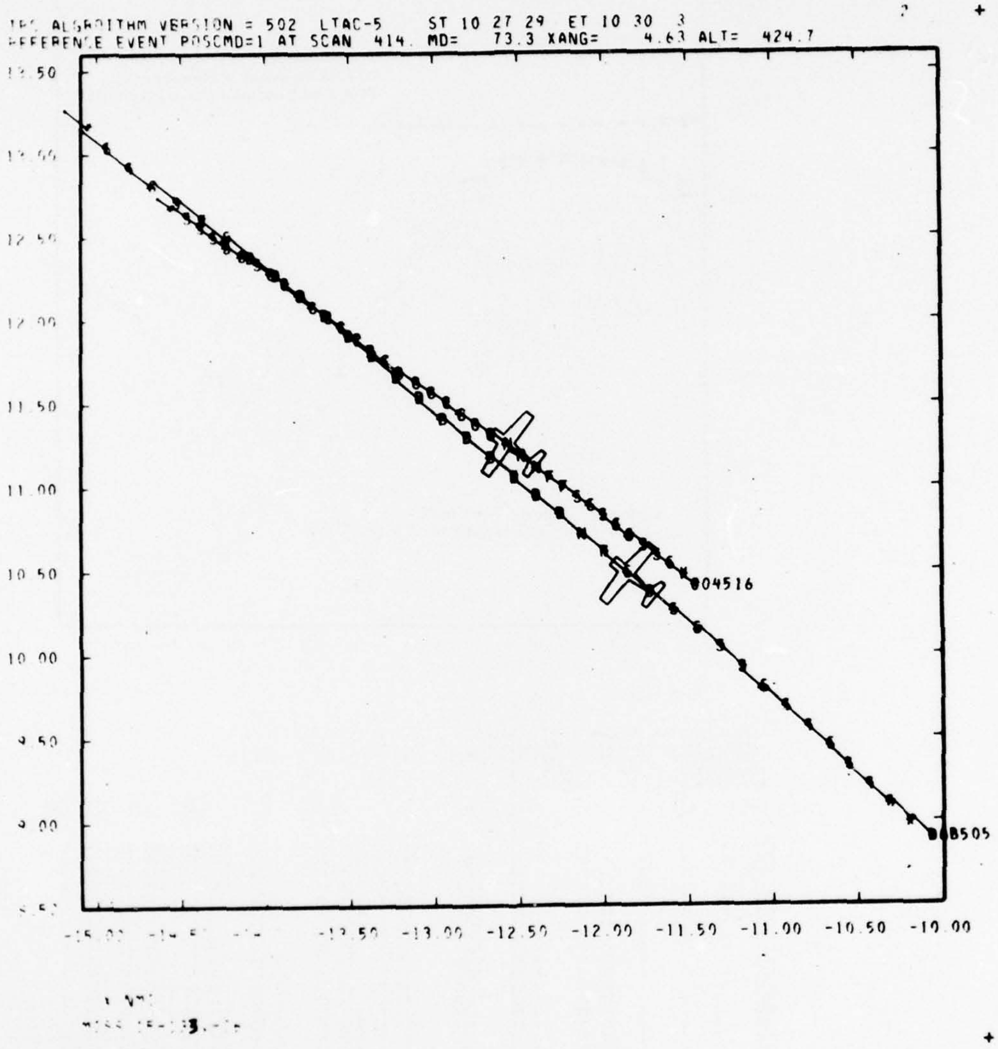
EXAMPLE 9
(Encounter 15-133-06)



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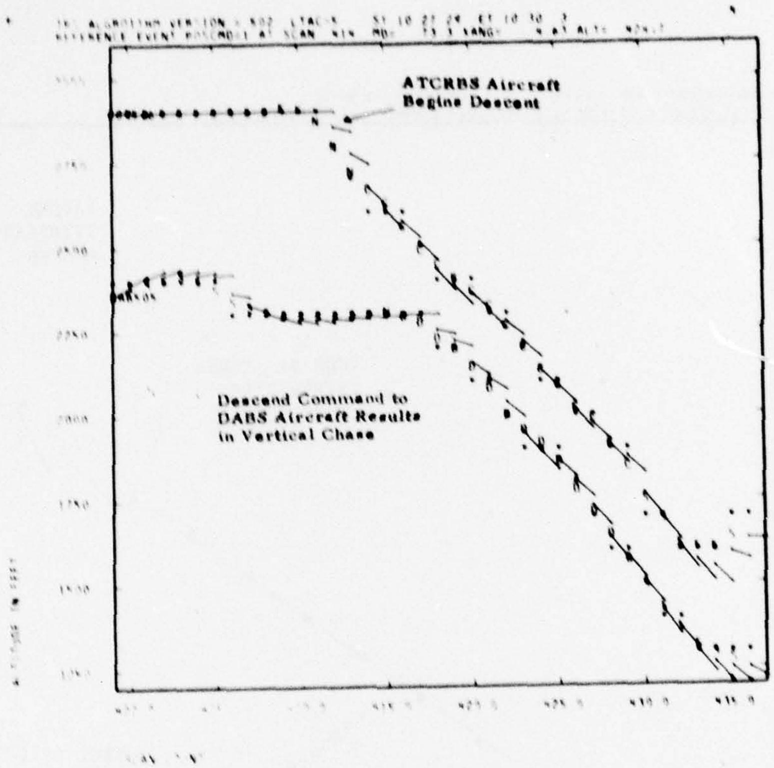


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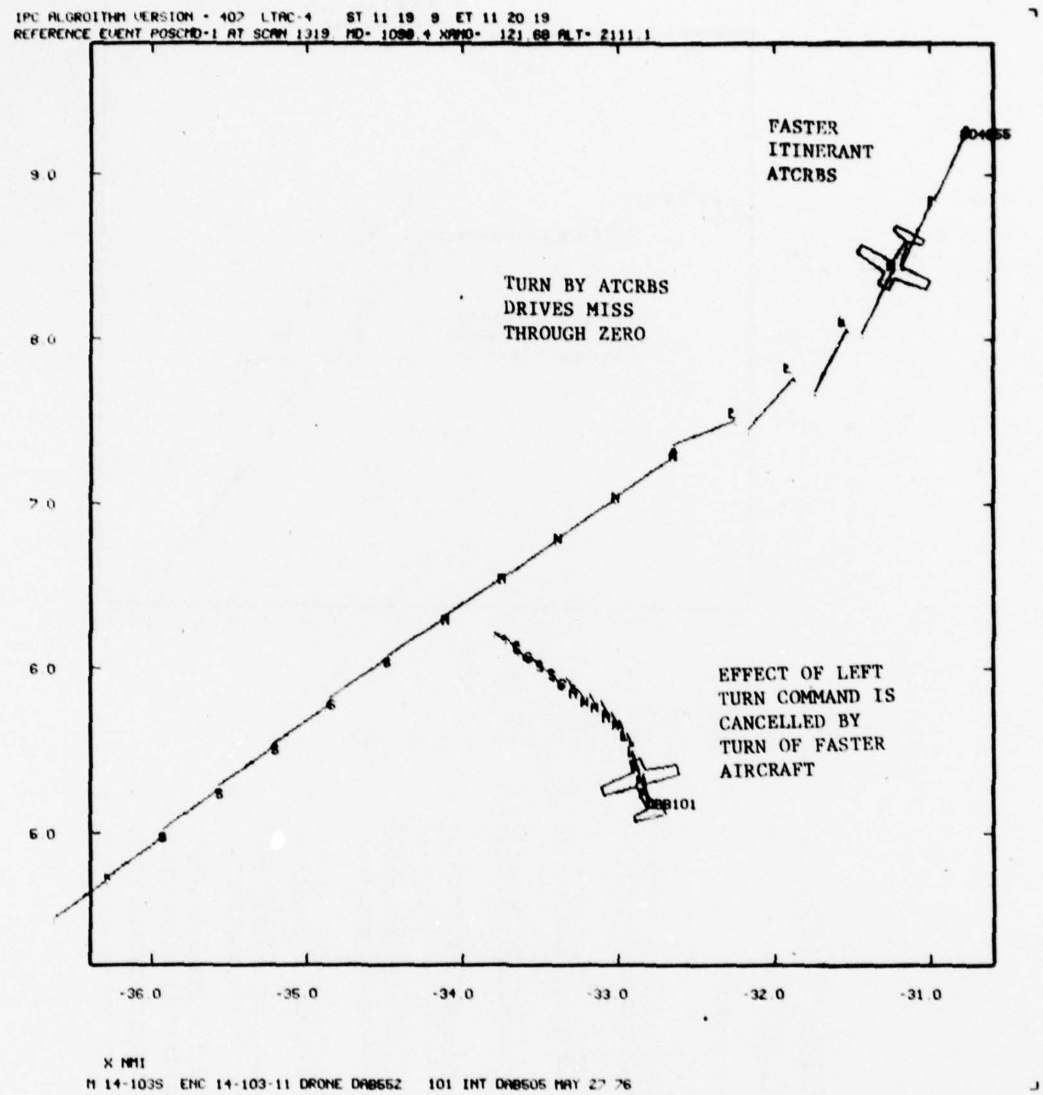
TCL ALGORITHM VERSION = 502  LTAC-X
SCAN = 50.434 CPAV = 207.285
CPA ON SCAN 427 SCPA = 282.831 SCPAH = 50.434 SCPAV = 278.298
AC1 TRACK =  1  ID = DABSON  IFR
AC2 TRACK = 40  ID = 00451A  VFR
```

SCAN	AC1	AC2	POS	TH	RANGE	RD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
399	X	X	0	125.00	2.11	3181	180.8	588.01	-3.25	179.90	-121.08	88	0
400	X	X	0	123.32	2.06	2718	92.7	519.92	-4.82	167.18	-114.65	88	0
401	X	[illegible]	0	120.13	1.99	1833	79.4	508.35	-6.36	101.27	-109.94	88	0
402	[illegible]	[illegible]	0	116.52	1.93	884	85.5	490.29	-5.71	123.35	-105.87	88	0
403	[illegible]	[illegible]	0	112.59	1.86	859	105.4	481.98	-4.57	189.11	-101.70	88	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

EXAMPLE 10
Encounter 14-103-11



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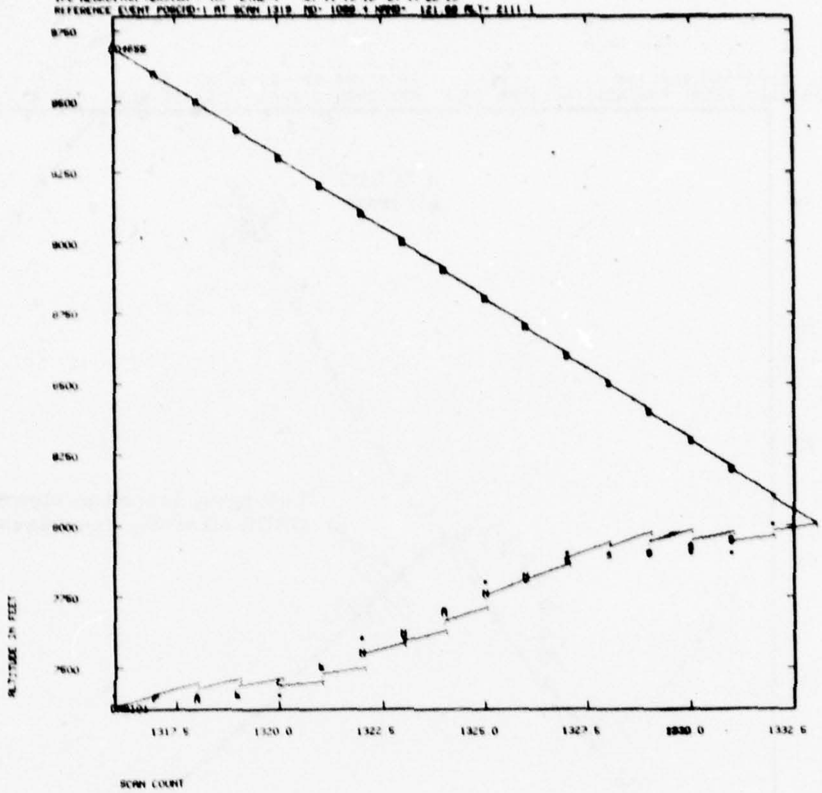
IPC ALGORITHM VERSION - 407 LTRC-4 ST 11 18 10 ET 11 20 18
REFERENCE EVENT FORCED-1 AT SCAN 1319 MD- 1080 4 HMD- 121 88 ALT- 2111 1



IPC ALGORITHM VERSION - 407 LTRC-4
CPMH - 5520 133 CPMV - 104 260
CPM ON SCAN 1328 SCPM - 5617 145 SCPMH - 5520 133 SCPMV - 1039 441
AC1 TRACK - 4 ID - DAB101 VFR
AC2 TRACK -102 ID - 004656 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
1316	X	S	0	36 87	6 11	1830	76 5	2493 36	-33 01	248 47	-2486 76	68	0
1317	X	S	-2	33 30	4 54	4583	67 1	2327 23	-34 70	0 0	-2091 26	68	2
1318	F	F	0	28 30	4 02	3367	64 4	2187 81	-33 86	0 0	-1892 26	68	2
1319	HR	HR	1	24 33	3 60	2936	64 6	2068 48	-32 00	0 0	-1621 34	68	2
1320	L	L	1	20 22	2 88	1873	66 1	1962 71	-29 68	0 0	-1362 48	68	2
1321	L	L	1	16 52	2 48	2420	67 8	1864 91	-27 60	0 0	-1067 62	68	2
1322	L	L	0	16 61	2 06	7682	59 4	1724 81	-29 04	0 0	-647 87	68	2
1323	HR	HL	0	9 90	1 68	6622	48 0	1553 30	-32 36	0 0	-676 44	68	2
1324	HR	HL	0	4 81	1 31	6624	42 9	1407 29	-32 81	0 0	-376 37	68	2
1325	HR	HL	0	-2 74	1 03	6400	35 3	1235 23	-35 00	0 0	-186 40	68	2
1326	HR	HL	0	-36 80	0 92	6570	27 6	1046 13	-37 81	0 0	-34 16	68	2
1327	HR	HL	0	7 68	0 96	6407	23 9	880 29	-37 20	0 0	125 48	68	0
1328	S	S	0	-2 26	1 15	6389	18 8	715 89	-38 19	0 0	265 44	68	0
1329	S	S	0	-8 12	1 46	6232	15 7	673 71	-36 66	0 0	419 94	68	0
1330	S	S	0	-13 23	1 79	6190	13 6	464 72	-33 76	0 0	662 21	68	0
1331	S	S	0	-18 04	2 16	6218	11 4	361 12	-30 71	0 0	686 27	68	0
1332	S	S	0	-22 77	2 66	6263	9 1	266 30	-28 00	0 0	864 93	68	0

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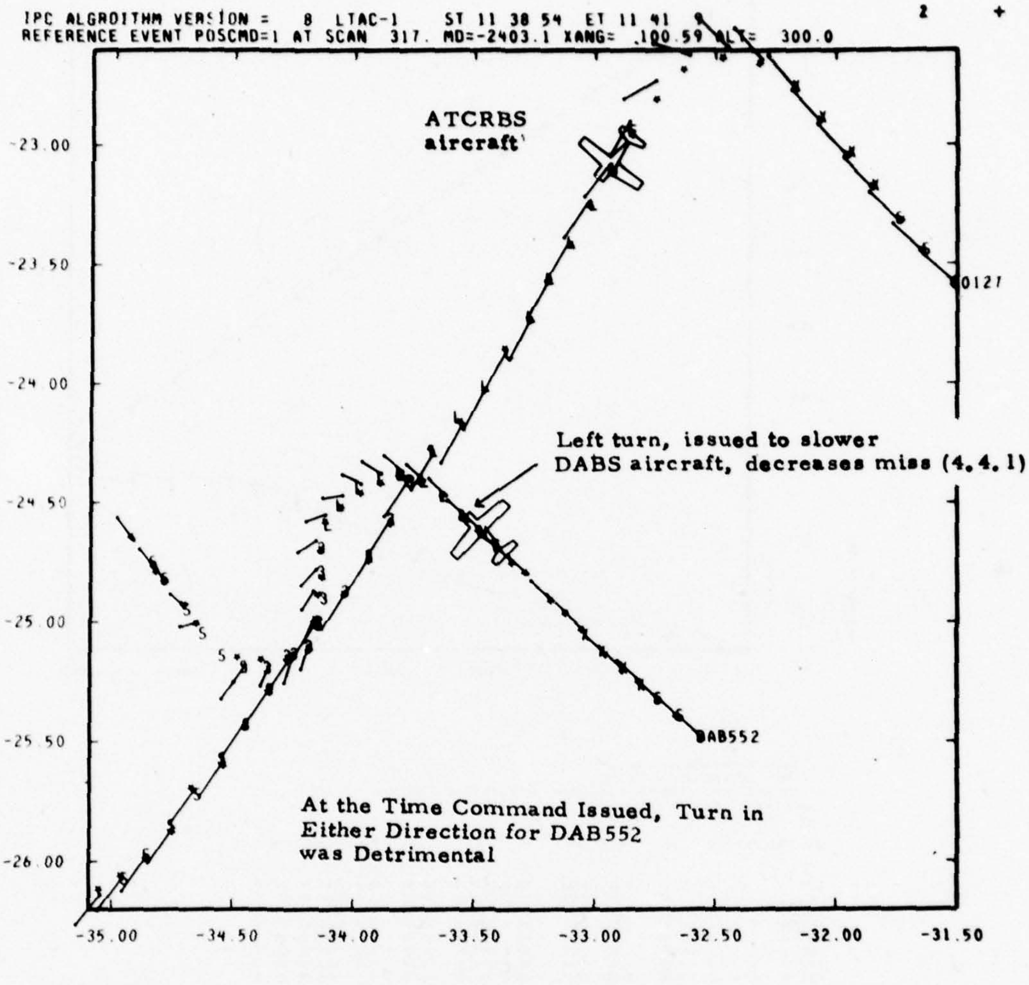
EXAMPLE 11
(Encounter 7-40-14)



MISS 7-40V-14 AUGUST, 1975 DRONE DAB101 INT ATCRBS

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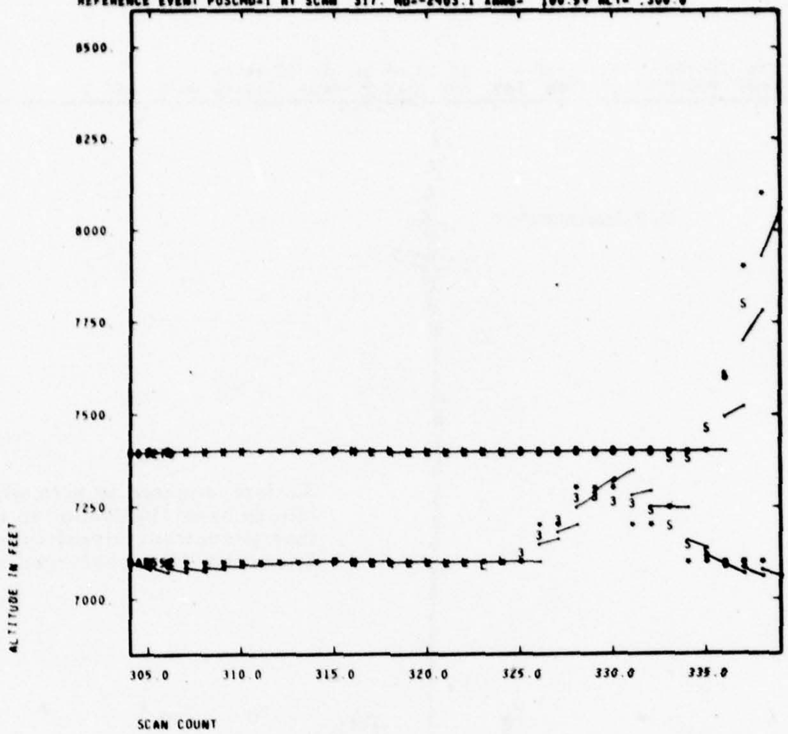
IPC ALGROITHM VERSION = 8 LTAC-1 ST 11 38 59 ET 11 41 9
REFERENCE EVENT POSCMD=1 AT SCAN 317. MD=-2403.1 XANG= 100.59 ALT= .300.0



IPC ALGORITHM VERSION = 8 LTAC-1
CPAH = 133.840 CPAV = 123.102
CPA ON SCAN 330 SCPA = 191.892 SCPAH = 133.840 SCPAV = 137.512
AC1 TRACK = 2 ID = DAB552 VFR
AC2 TRACK = 65 ID = 001270 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
304	S	S	0	0.0	2.14	12814.	0.0	271.54	0.0	271.54	18.40	64	0
305	S	S	0	0.0	2.17	12845.	0.0	294.78	0.0	294.78	24.03	64	0
306	S	S	0	0.0	2.19	12821	0.0	308.01	0.0	308.01	30.45	64	0
307	S	S	0	0.0	2.24	12634.	0.0	313.97	0.0	313.97	42.23	64	0
308	X	X	0	0.0	2.28	12304.	0.0	315.10	0.0	315.10	55.93	64	0
309	X	X	0	0.0	2.34	11886	0.0	313.55	0.0	313.55	73.73	64	0
310	X	X	0	0.0	2.40	11505.	0.0	310.77	0.0	310.77	92.53	64	0
315	X	X	-2	48.76	2.10	967.	1327.0	300.20	-0.23	285.72	-301.36	64	2
316	F	F	0	33.55	1.87	3088.	1491.1	299.62	-0.20	286.76	-341.51	64	2
317	NR	NR	1	27.49	1.63	1768.	1889.5	299.37	-0.16	289.23	-302.47	64	2
318	L	L	1	21.79	1.42	1952.	2653.8	299.32	-0.11	292.11	-274.17	64	2
319	L	L	1	16.06	1.19	2416.	4159.2	299.40	-0.07	294.79	-232.79	64	2
320	L	L	1	11.76	0.99	2720.	7506.8	299.52	-0.04	296.97	-187.74	64	2
321	L	L	1	8.07	0.83	3023	17774.2	299.66	-0.02	298.58	-140.32	64	2
322	L	L	1	5.76	0.73	2991.	100.0	299.78	0.0	299.65	-106.37	64	2
323	L	L	1	2.98	0.64	3026	-49723.6	299.88	0.01	299.88	-74.15	64	2
324	L	L	1	-0.03	0.59	2946	-31923.2	299.95	0.01	299.95	-43.97	64	2
325	L	L	3	-6.32	0.53	2600	-30117.8	299.99	0.01	299.99	-34.41	64	2
326	R	L	3	-14.67	0.46	1925	-33977.7	300.02	0.01	300.02	-29.87	64	2
327	R	L	3	-29.32	0.37	1263	70.9	253.62	-3.58	24.81	-23.91	64	2
328	R	L	3	-53.31	0.27	745	44.2	221.13	-5.01	0.0	-17.67	64	2
329	R	L	3	-89.37	0.17	133	17.8	154.22	-8.66	0.0	-12.91	64	2
330	R	L	3	-177.31	0.11	387	11.8	110.46	-9.36	0.0	-6.69	64	2
331	R	L	3	-847.33	0.03	138	10.2	85.60	-8.39	0.0	-1.93	64	2
332	R	L	0	0.0	0.09	421	0.0	120.84	0.0	120.84	4.28	64	0
333	S	S	0	0.0	0.24	867	0.0	151.11	0.0	151.11	15.08	64	0
334	S	S	0	0.0	0.33	920	0.0	152.19	0.0	152.19	23.09	64	0
334			0	0.0	0.33	920	0.0	152.19	0.0	152.19	23.09	64	0
335	S	S	0	0.0	0.70	929	0.0	241.30	0.0	241.30	75.50	64	0
336	S	S	0	0.0	0.92	950	0.0	281.99	0.0	281.99	166.78	64	0
336			0	0.0	0.92	950	0.0	281.99	0.0	281.99	166.78	64	0
337	S	S	0	0.0	1.14	1286.	0.0	398.30	0.0	398.30	237.64	64	0
337			0	0.0	1.14	1286	0.0	398.30	0.0	398.30	237.64	64	0
338	S	S	0	0.0	1.30	577	0.0	614.48	0.0	614.48	256.38	64	0

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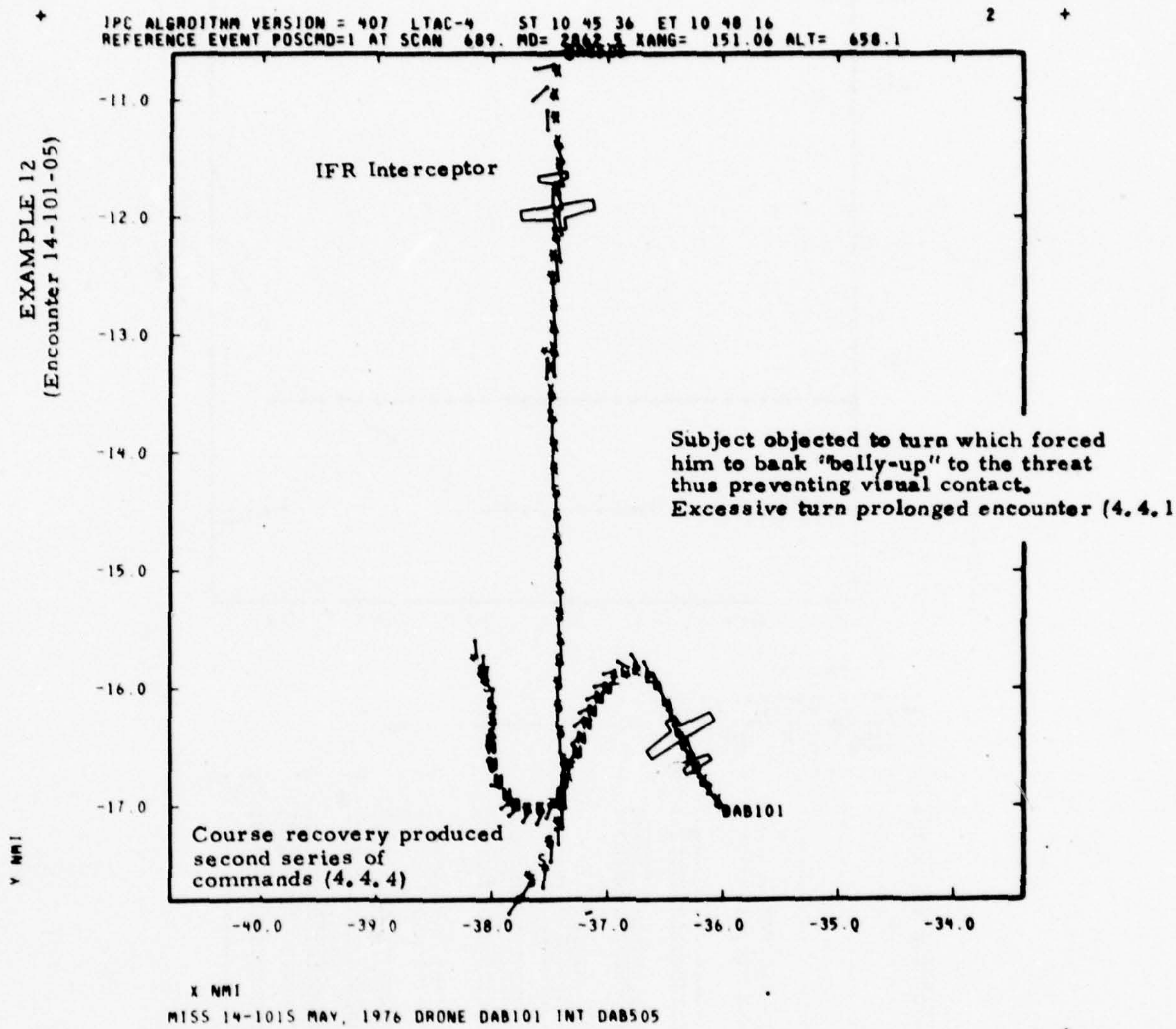
EXAMPLE 12
(Encounter 14-101-05)



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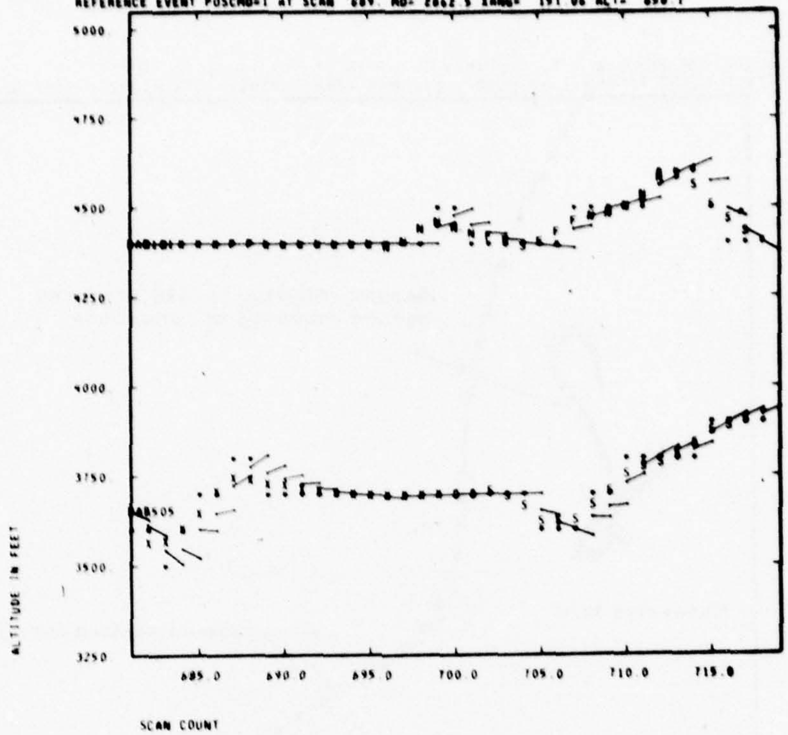
IPC ALGROITHM VERSION = 407 LTAC-4 ST 10 45 36 ET 10 48 16
REFERENCE EVENT POSCMD=1 AT SCAN 689 MD= 2062 5 XANG= 151 06 ALT= 650 1



IPC ALGORITHM VERSION = 407 LTAC-4
CPAH = 3690 271 CPAV = 498 998
CPA ON SCAN 711 SCPA = 3767 843 SCPAH = 3690 271 SCPAV = 760 619
AC1 TRACK = 1 ID = DABS05 IFR
AC2 TRACK = 2 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
681	X	X	0	260 27	6 81	30818	-256 5	685 98	2 67	685 98	-635 87	68	0
682	X	X	0	320 85	6 61	33037	-121 8	745 04	6 12	745 04	-486 21	68	0
683	X	X	0	259 79	6 45	30266	-111 1	784 74	7 06	784 74	-571 47	68	0
684	X	X	0	127 68	6 11	15935	-86 3	854 50	9 91	854 50	-1043 58	68	0
685	X	X	0	87 52	5 84	1427	-128 3	851 83	6 64	851 83	-1387 04	68	0
686	X	X	0	76 57	5 46	8266	-1136 4	797 00	0 70	797 00	-1383 76	68	0
687	X	X	0	70 41	5 18	3292	291 1	753 64	-2 59	577 62	-1350 40	68	0
688	X	F	-2	65 42	4 88	2586	93 1	676 27	-7 27	182 11	-1286 70	68	2
689	X	F	1	60 97	4 57	1400	71 3	623 98	-8 75	28 88	-1210 24	68	2
690	X	L	1	52 86	4 16	447	128 3	638 80	-4 98	300 13	-1149 86	68	2
691	X	L	1	50 47	3 90	603	287 6	655 34	-2 28	500 42	-1055 71	68	2
692	X	L	1	47 19	3 60	1276	1921 1	670 75	-0 47	638 66	-959 83	68	2
693	X	L	1	42 22	3 26	1219	-1150 5	683 26	0 59	683 26	-874 71	68	2
694	X	L	1	37 94	2 95	678	-692 1	692 37	1 08	692 37	-790 12	68	2
695	X	L	1	40 02	2 75	1983	-591 4	698 37	1 18	698 37	-646 19	68	2
696	X	L	0	63 98	2 73	5458	-658 8	701 85	1 07	701 85	-400 56	68	2
697	X	NR	0	54 90	2 53	5081	-663 3	706 48	1 07	706 48	-397 30	68	2
698	X	NR	0	56 60	2 39	5584	-1840 5	704 48	0 38	704 48	-340 59	68	2
699	X	NR	0	59 43	2 27	5832	-6059 5	702 94	0 12	702 94	-291 70	68	2
700	X	NR	0	61 46	2 16	5885	-219 8	748 24	3 40	748 24	-251 88	68	2
701	S	NR	0	65 28	2 07	5951	-168 0	780 12	4 64	780 12	-216 41	68	2
702	S	NR	0	71 61	2 01	6119	-572 8	753 75	1 32	753 75	-183 54	68	0
703	S	F	0	74 62	1 92	6054	1047 9	731 80	-0 70	684 32	-159 03	68	0
704	S	F	0	75 46	1 83	5996	431 7	715 49	-1 66	602 79	-141 08	68	0
705	S	S	0	71 35	1 72	5779	363 6	704 55	-1 94	572 77	-129 35	68	0
706	S	F	0	70 05	1 64	5742	-500 6	744 30	1 49	744 30	-117 73	68	0
707	S	F	-2	54 70	1 46	5507	-247 2	773 58	3 13	773 58	-114 22	68	2
708	S	F	0	41 73	1 29	5277	-120 4	839 40	6 94	839 40	-109 11	68	2
709	S	ND	0	32 98	1 12	5024	-180 1	837 45	4 65	837 45	-97 83	68	2
710	S	ND	0	24 18	0 94	4584	-303 2	830 91	2 74	830 91	-81 21	68	2
711	S	ND	0	11 48	0 71	4007	373 3	776 45	-2 08	635 02	-53 19	68	2
712	S	ND	0	7 67	0 62	3762	169 6	736 20	-4 34	441 08	-10 00	68	2
713	S	ND	0	-5 39	0 72	3926	467 5	755 72	-1 62	645 80	88 81	68	0
714	S	S	0	-8 81	0 86	4180	-4058 2	772 47	0 09	772 47	143 01	68	0
715	S	S	0	-10 61	1 03	3687	-792 7	785 44	0 99	785 44	229 34	68	0
716	S	S	0	-14 52	1 27	3649	131 1	701 71	-5 35	337 67	305 44	68	0
717	S	S	0	-19 43	1 64	3024	52 8	595 73	-11 28	0 0	426 29	68	0
718	S	S	0	-26 06	1 84	5682	40 8	525 31	-12 87	0 0	400 70	68	0

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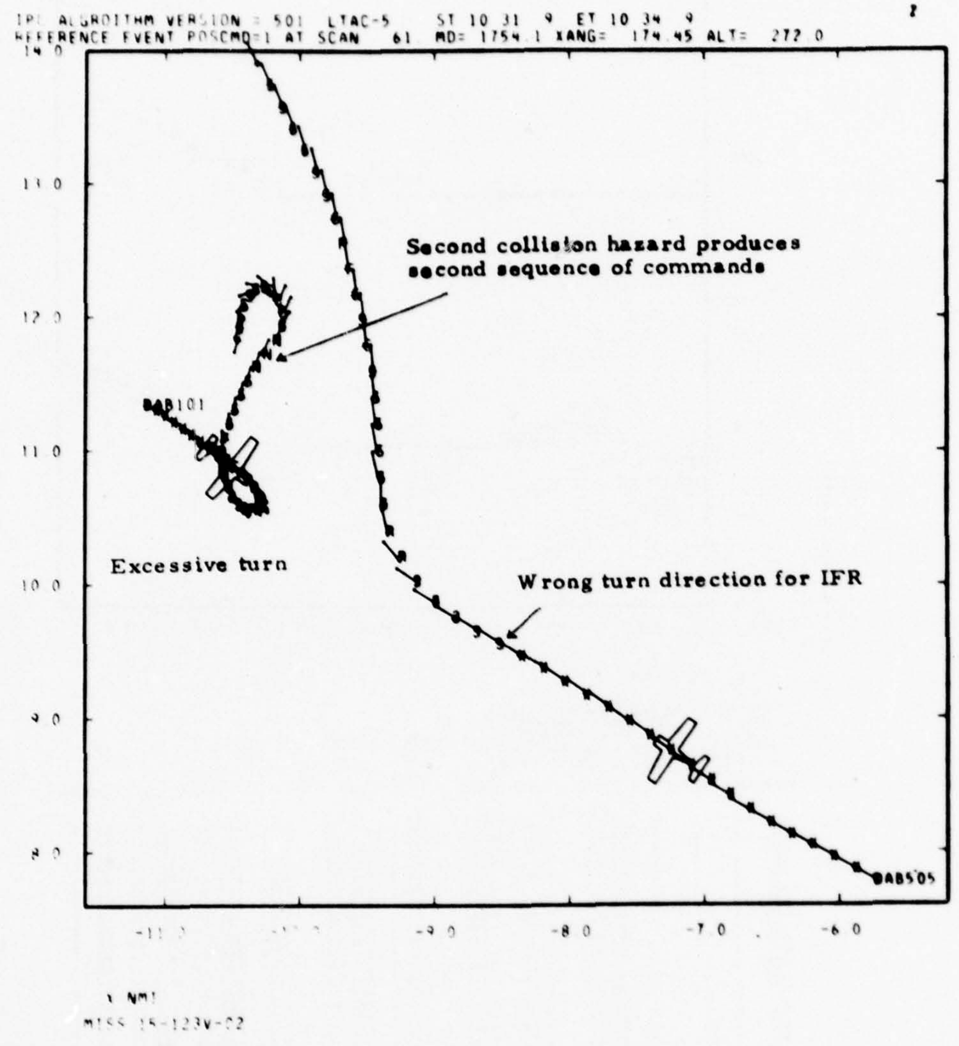
EXAMPLE 13
(Encounter 15-123-02)



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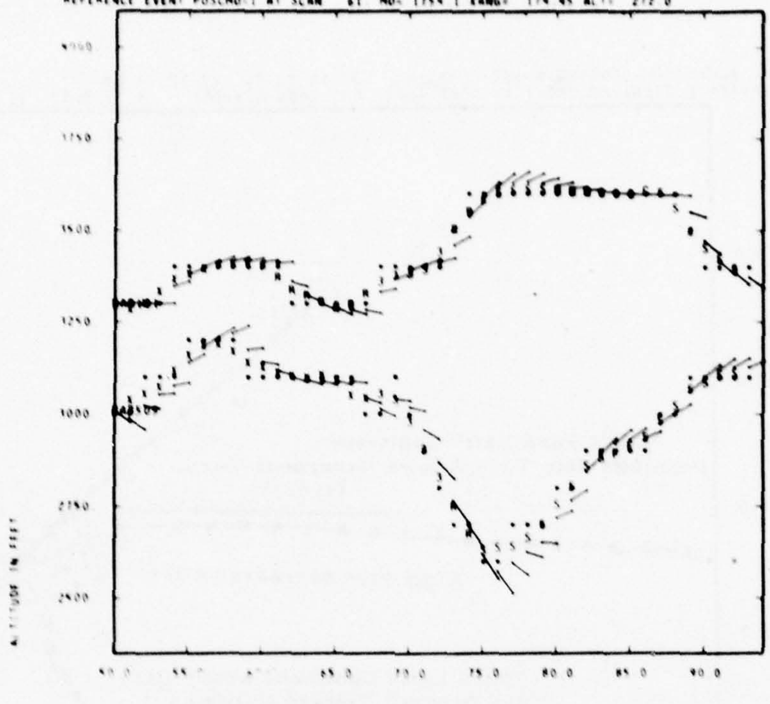
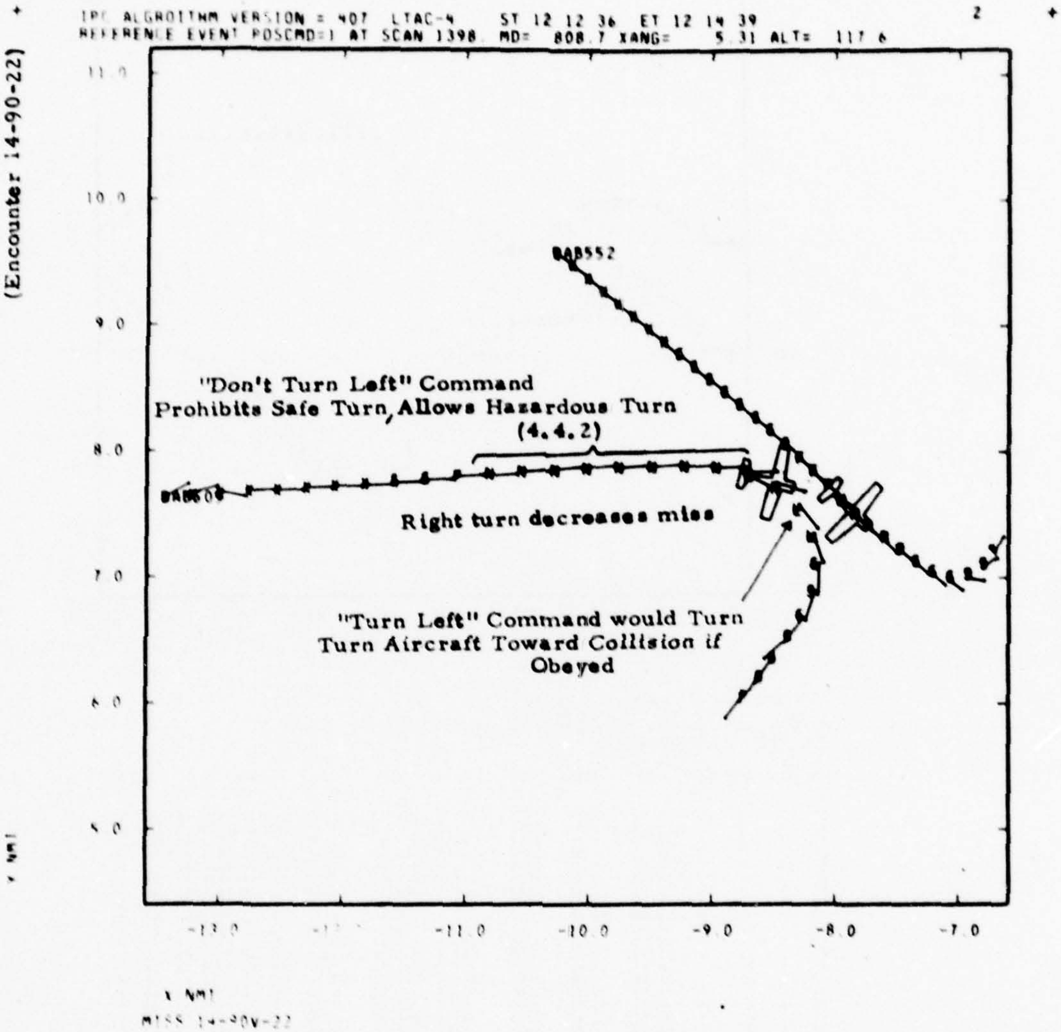
TPC ALGORITHM VERSION = 501 LTAC-5 ST 10.31. 9 ET 10.34. 9
REFERENCE EVENT POSCMD=1 AT SCAN 61. MD= 1759.1 RANGE= 174.95 ALT= 272.0



TPC ALGORITHM VERSION = 501 LTAC-5
CPAH = 3625.982 CPAV = 197.458
CPR ON SCAN 84 SCPA = 3695.809 SCPAH = 3627.222 SCPAV = 108.705
AC1 TRACK = 2 ID = DAB505 IFR
AC2 TRACK = 1 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
50	X	X	0	109.13	6.75	3177	-34.3	-250.30	-7.31	250.30	-1492.66	68	0
51	X	X	0	104.27	6.49	2916	-36.3	-289.69	-7.97	289.69	-1443.20	68	0
52	X	X	0	99.38	6.23	2741	-43.5	-312.25	-7.18	312.25	-1392.88	68	0
53	X	X	0	94.66	5.96	2383	-120.1	-276.30	-2.29	276.30	-1339.82	68	0
54	X	X	0	90.05	5.70	2450	371.4	-246.04	0.66	201.00	-1284.91	68	0
55	X	X	0	85.98	5.44	2162	-209.4	-269.59	-1.29	269.59	-1225.63	68	0
56	X	X	0	82.07	5.18	2008	185.7	-240.21	1.29	152.23	-1164.37	68	0
57	X	X	0	77.97	4.92	1419	47.7	-218.68	2.49	49.06	-1104.44	68	0
58	X	Y	0	73.49	4.66	976	73.5	-204.44	2.78	15.38	-1047.30	68	0
59	X	Y	0	69.13	4.40	260	77.5	-196.19	2.53	24.00	-989.73	68	0
60	X	Y	-2	64.72	4.13	168	-169.4	-238.68	-1.41	238.68	-931.47	68	?
61	X	Y	1	60.90	3.88	869	-81.3	-270.28	-3.32	270.28	-871.04	68	?
62	X	R	1	56.17	3.61	1053	-75.3	-291.50	-3.87	291.50	-814.10	68	?
63	X	R	1	51.84	3.35	1355	-1581.5	-257.70	-0.16	257.70	-755.61	68	?
64	X	R	1	47.89	3.09	1604	124.8	-231.29	1.85	105.28	-695.30	68	?
65	X	R	1	44.18	2.85	1695	74.7	-212.63	2.67	31.29	-634.06	68	?
66	X	R	1	41.37	2.62	1918	73.4	-200.81	2.72	15.93	-570.76	68	?
67	X	R	1	39.24	2.42	2042	82.5	-194.36	2.36	34.20	-507.29	68	?
68	X	R	3	38.08	2.24	2218	-195.4	-238.11	-1.63	238.11	-444.90	68	?
69	R D	R C	3	40.41	2.10	3221	-45.3	-316.85	-6.99	316.85	-361.59	68	?
70	R D	R C	3	46.73	1.98	2716	-60.1	-329.66	-5.40	329.66	-278.95	68	?
71	R D	R C	3	47.90	1.87	689	-51.4	-371.69	-7.23	371.69	-239.28	68	?
72	R D	R C	3	44.55	1.75	1279	-42.1	-447.37	-10.61	447.37	-222.30	68	?
73	R D	R C	0	44.46	1.62	523	-37.7	-541.44	-14.37	541.44	-187.32	68	?
74	RNC	RND	0	44.93	1.49	2496	-32.7	-693.79	-21.21	693.79	-152.48	68	?
75	RNC	RND	0	74.76	1.38	7145	-33.1	-836.96	-25.27	836.96	-75.63	68	0
76	<	Y	0	85.75	1.28	7070	-35.6	-969.19	-27.26	969.19	-53.70	68	0
77	<	<	0	41.89	1.19	5005	-42.8	-1049.47	-24.40	1049.47	-89.41	68	0
78	<	<	0	39.19	1.11	4926	-64.4	-1032.05	-15.90	1032.05	-77.56	68	0
79	<	<	0	37.48	1.04	4867	-111.1	-1006.36	-9.06	1006.36	-65.87	68	0
80	<	<	0	34.45	0.96	4730	-239.6	-977.25	-4.08	977.25	-55.41	68	?
81	<	ND	0	29.10	0.88	4504	344.3	-904.19	2.63	725.56	-46.34	68	?
82	<	ND	0	17.42	0.77	4030	145.6	-849.41	5.84	452.45	-39.40	68	?
83	<	ND	1	7.41	0.68	3741	75.4	-767.31	10.17	75.41	-30.28	68	?
84	<	C	1	-6.22	0.60	1444	64.6	-713.34	11.03	0.0	-21.19	68	?
85	Y	C	1	-17.55	0.58	1489	68.4	-682.49	9.90	8.95	-11.00	68	?
86	Y	C	1	6.47	0.64	1861	84.4	-668.48	7.87	111.05	-10.00	68	?
87	<	C	0	-15.17	0.70	1650	117.8	-665.50	5.65	281.21	10.16	68	0
88	<	<	0	-12.68	0.81	1860	87.7	-622.45	7.09	140.05	84.07	68	0
89	<	<	0	-15.15	0.96	1651	87.1	-596.18	6.85	110.54	138.73	68	0
90	<	<	0	-17.44	1.14	1998	38.8	-489.85	12.64	0.0	199.55	68	0
91	<	<	0	-20.12	1.36	2861	21.5	-371.47	17.37	0.0	269.69	68	0
92	<	<	0	-21.45	1.60	3991	17.3	-300.56	17.41	0.0	335.12	68	0
93	<	<	0	-23.63	1.81	3411	17.5	-261.12	14.92	0.0	391.82	68	0

EXAMPLE 14
(Encounter 14-90-22)



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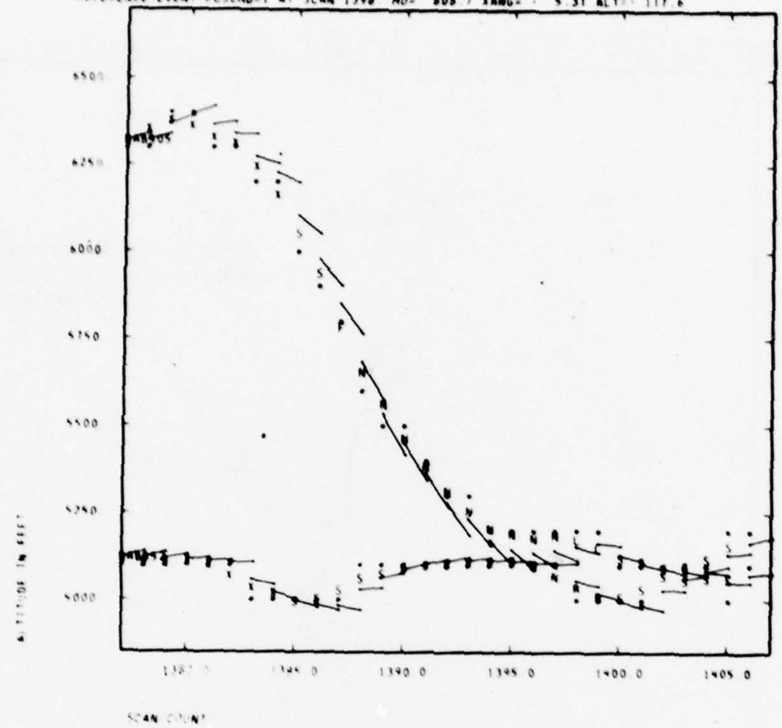
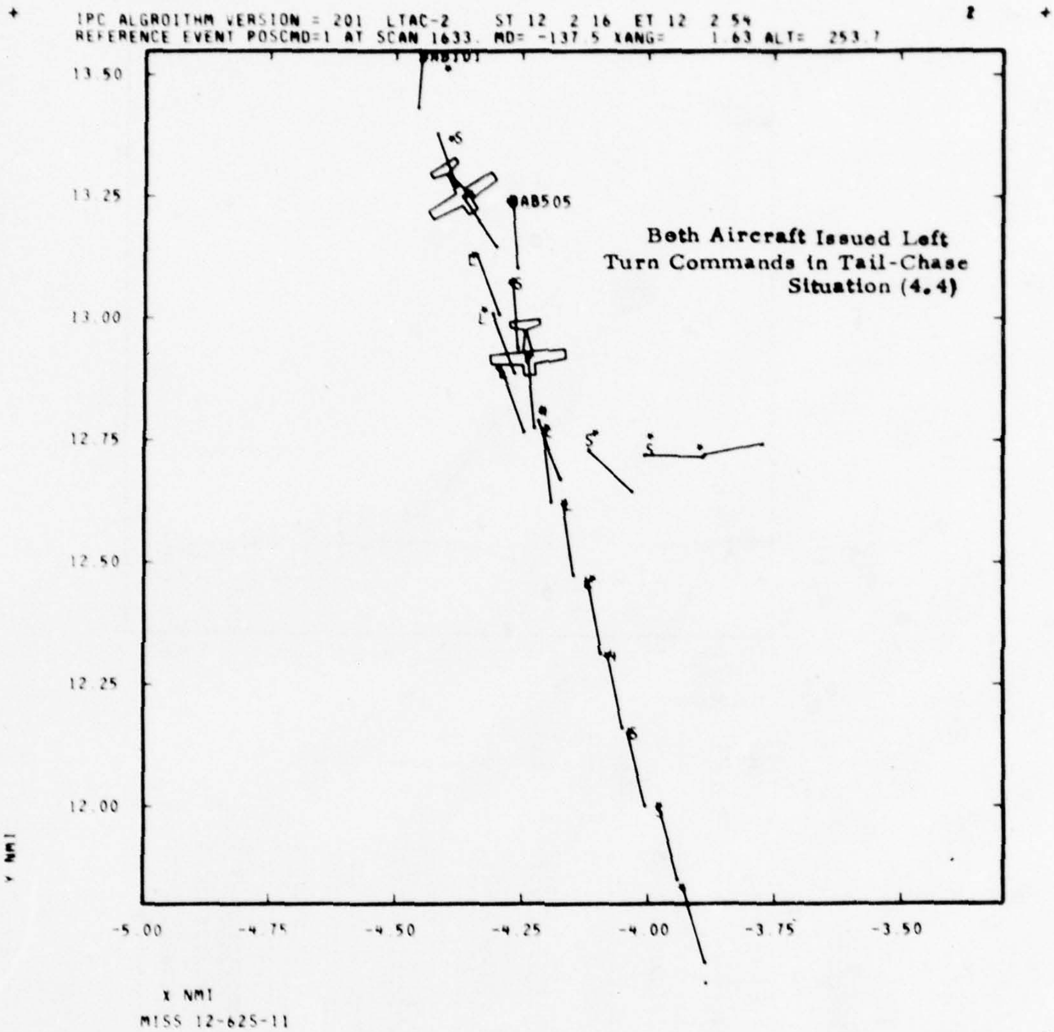
IPC ALGROITHM VERSION = 407 LTAC-4 ST 12 12 36 ET 12 14 39
REFERENCE EVENT POSCMD=1 AT SCAN 1398 MD= 808.7 XANG= 5.31 ALT= 117.6



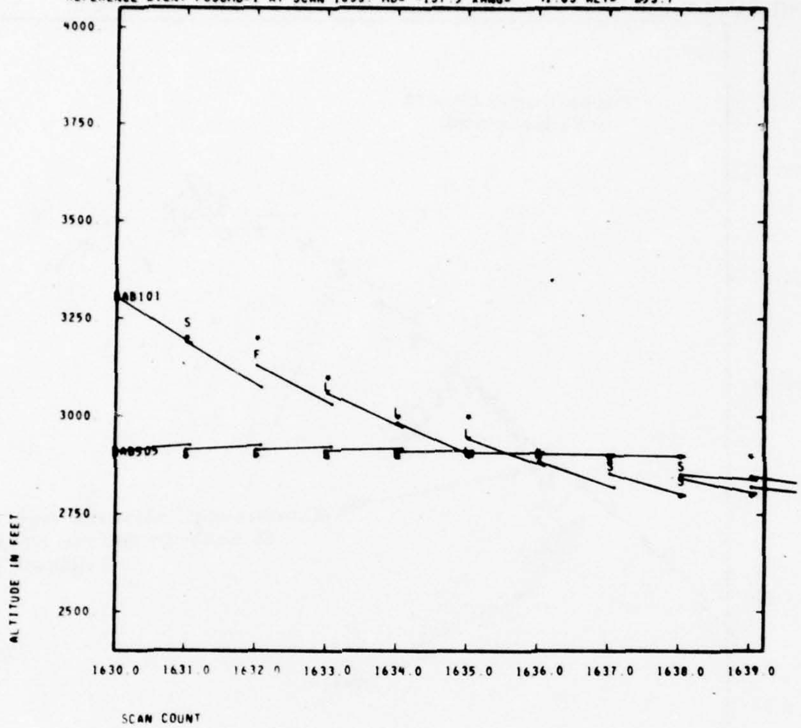
IPC ALGORITHM VERSION = 407 LTAC-4
CPAH = 3640.247 CPAV = 20.156
CPA ON SCAN 1399 SCPA = 3642.941 SCPAH = 3640.247 SCPAV = 140.066
AC1 TRACK = 1 ID = DABS05 VFR
AC2 TRACK = 2 ID = DABS52 IFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
1377	X	X	0	93.35	3.87	15857	-2765.5	-1199.02	-0.43	1199.02	-557.64	68	0
1378	X	X	0	94.38	3.73	15344	-2960.7	-1200.50	-0.41	1200.50	-504.70	68	0
1379	X	X	0	98.67	3.57	11557	-3618.0	-1201.22	-0.[illegible]	1201.22	-447.14	68	0
1380	X	X	0	137.11	3.43	1406	-342.8	-1247.81	-3.64	1247.81	-296.04	68	0
1381	X	X	0	98.44	3.28	6881	-262.1	-1280.33	-4.89	1280.33	-375.00	68	0
1382	X	X	0	92.04	3.13	6063	-860.7	-1254.17	-1.46	1254.17	-363.16	68	0
1383	X	X	0	86.21	2.98	5685	2072.9	-1232.34	0.59	1191.92	-350.35	68	0
1384	X	X	0	79.88	2.83	5434	761.6	-1215.98	1.60	1107.41	-338.00	68	0
1385	X	X	0	73.96	2.68	5364	633.2	-1204.91	1.90	1075.51	-324.14	68	0
1386	S	S	0	68.39	2.53	5339	128.7	-1105.49	8.59	521.42	-308.92	68	0
1387	S	S	-2	62.55	2.37	5379	69.1	-990.61	14.33	16.33	-293.08	68	2
1388	F	S	0	55.68	2.20	5278	46.5	-869.43	18.71	0.0	-277.87	68	2
1389	NL	S	0	48.81	2.02	5068	23.0	-655.38	28.54	0.0	-261.90	68	2
1390	NL	S	0	42.44	1.85	4949	14.3	-471.89	33.08	0.0	-243.33	68	2
1391	NL	S	0	36.97	1.69	4822	11.8	-362.98	30.75	0.0	-222.02	68	2
1392	NL	S	0	31.65	1.52	4703	9.3	-263.71	28.46	0.0	-198.76	68	2
1393	NL	S	0	26.71	1.37	4485	6.4	-169.24	26.51	0.0	-174.94	68	2
1394	NL	F	0	21.16	1.21	4381	5.7	-122.67	21.66	0.0	-148.80	68	2
1395	NL	F	0	15.39	1.06	4235	3.2	-62.60	19.31	0.0	-122.72	68	2
1396	NL	F	0	9.59	0.92	4058	2.4	-35.98	15.26	0.0	-97.86	68	2
1397	NL	NR	0	2.47	0.80	3828	2.8	-30.93	10.89	0.0	-74.47	68	2
1398	NL	NR	1	-6.71	0.68	2453	5.5	-38.24	6.98	0.0	-64.11	68	2
1399	I	R	1	-23.55	0.59	2603	204.2	-97.44	0.48	65.00	-34.63	68	2
1400	I	R	0	84.15	0.56	3355	-96.8	-143.94	-3.08	193.94	10.91	68	0
1401	S	S	0	4.96	0.67	2617	-115.1	-130.58	-1.13	130.58	86.00	68	0
1402	S	S	0	-3.30	0.85	1514	1773.0	-118.94	0.07	114.38	169.55	68	0
1403	S	S	0	-8.59	1.10	135	35.5	-63.68	4.10	0.0	273.56	68	0
1404	S	S	0	-13.23	1.39	1087	4.4	-24.84	5.66	0.0	375.78	68	0
1405	S	S	0	-17.73	1.71	1459	0.1	-0.48	5.69	0.0	487.13	68	0
1406	S	S	0	-21.21	2.04	4093	-41.7	-80.14	-1.92	80.14	617.87	68	0

EXAMPLE 15
(Encounter 12-62-11)



IPC ALGROITHM VERSION = 201 LTAC-2 ST 12 2 16 ET 12 2 54
REFERENCE EVENT POSCMD=1 AT SCAN 1633. MD= -137.5 XANG= -1.63 ALT= 253.7



IPC ALGORITHM VERSION = 201 LTAC-2
CPAH = 1822.379 CPAV = 11.813
CPA ON SCAN 1630 SCPA = 1863.647 SCPAH = 1822.379 SCPAV = 390.021
AC1 TRACK = 2 ID = DAB505 VFR
AC2 TRACK = 1 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
1630	S	S	0	0.0	0.34	844.	0.0	-531.67	0.0	531.67	33.48	32.	0
1631	S	S	0	0.0	0.35	120.	0.0	-394.55	0.0	394.55	11.05	32.	0
1632	S	S	-2	-65.55	0.34	1912.	8.6	-275.30	32.21	0.0	-10.00	32.	2
1633	F	F	1	-67.99	0.36	2086.	8.1	-215.14	26.71	0.0	5.60	32.	2
1634	L	L	1	-65.61	0.38	2152.	6.4	-148.55	23.39	0.0	-10.00	32.	2
1635	L	L	1	-56.74	0.42	2288.	3.4	-74.01	21.71	0.0	-10.00	32.	2
1636	L	L	4	-44.25	0.46	2276.	2.1	-37.66	17.68	0.0	-10.00	32.	2
1637	L	L	0	0.0	0.50	2125.	0.0	19.36	0.0	19.36	10.85	32.	0
1638	S	S	0	0.0	0.59	2668.	0.0	47.02	0.0	47.02	29.43	32.	0
1639	S	S	0	0.0	0.72	2238.	0.0	8.83	0.0	8.83	92.54	32.	0

Note: DOT > 0 when command generated

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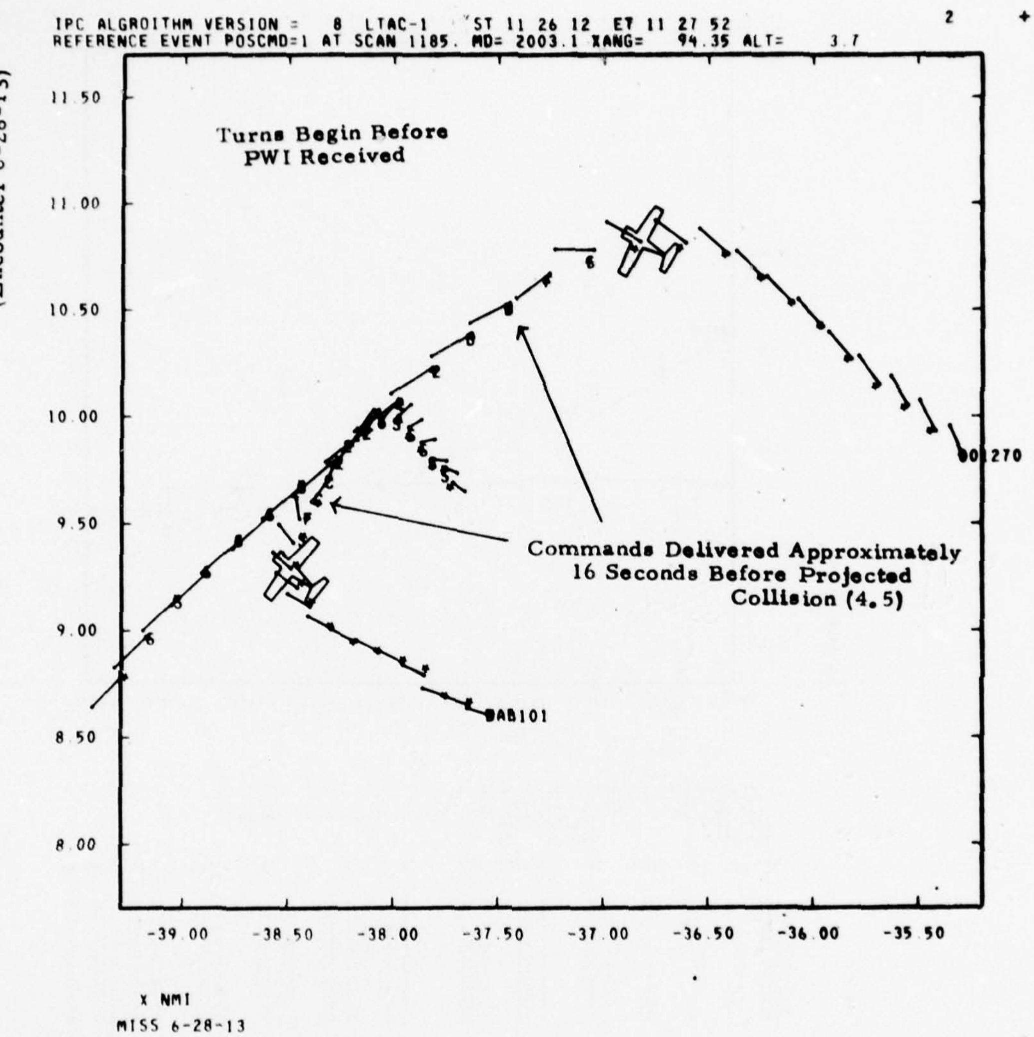
EXAMPLE 16
(Encounter 6-28-13)



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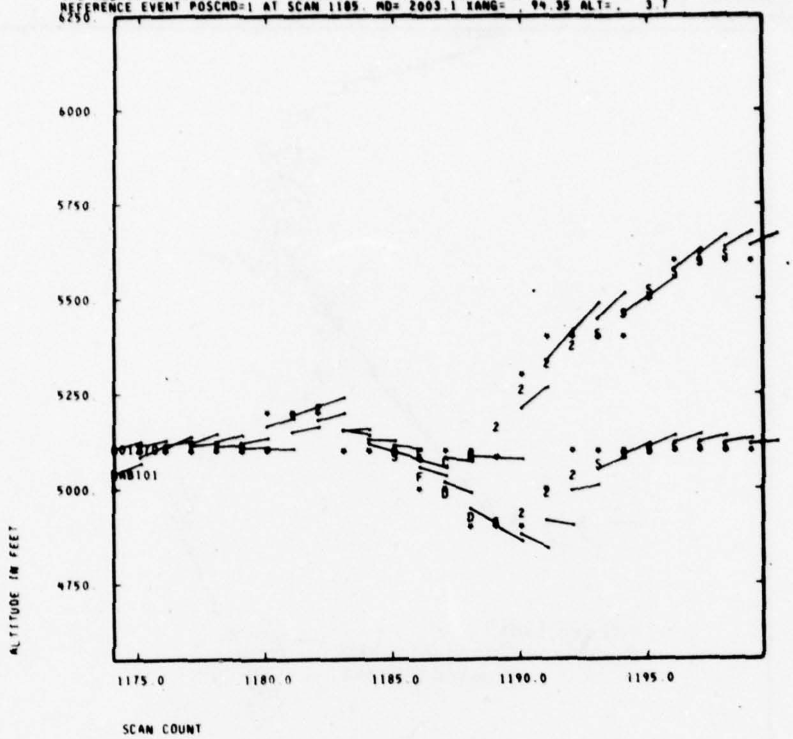
IPC ALGROITHM VERSION = 8 LTAC-1 ST 11 26 12 ET 11 27 52
REFERENCE EVENT POSCMD=1 AT SCAN 1185. MD= 2003.1 XANG= , 94.35 ALT=, 3.7



IPC ALGORITHM VERSION = 8 LTAC-1
CPAH = 303.673 CPAV = 3.719
CPA ON SCAN 1191 SCPA = 456.158 SCPAH = 303.673 SCPAV = 340.387
AC1 TRACK = 1 ID = DAB101 IFR
AC2 TRACK = 42 ID = 001270 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
1185			0	195.37	2.26	11330.	-2.4	11.16	4.61	11.16	-87.08	64.	0
1186	S	S	-2	50.29	1.97	1891.	-4.5	15.91	3.54	15.91	-252.22	64.	2
1187	F	F	1	22.21	1.66	2015.	-51.4	-19.74	-0.38	19.74	-381.14	64.	2
1188	C	D	1	13.41	1.32	1516.	-13.8	-63.93	-4.64	63.93	-356.28	64.	2
1189	C	D	2	6.48	0.98	591.	-15.1	-138.70	-9.18	138.70	-276.53	64.	2
1190	R C	R D	2	-1.22	0.64	270.	-18.9	-178.52	-9.44	178.52	-190.58	64.	2
1191	R C	R D	2	-14.97	0.31	2.	-14.2	-331.48	-23.36	331.48	-94.78	64.	2
1192	R C	R D	2	-474.48	0.02	118.	-17.4	-420.42	-24.12	420.42	-3.71	64.	2
1193	R C	R D	0	0.0	0.25	67.	0.0	-415.75	0.0	415.75	73.02	64.	0
1194	S	S	0	0.0	0.50	169.	0.0	-396.59	0.0	396.59	142.63	64.	0
1195	S	S	0	0.0	0.77	313.	0.0	-371.99	0.0	371.99	213.36	64.	0
1196	S	S	0	0.0	0.98	510.	0.0	-394.86	0.0	394.86	252.99	64.	0
1197	S	S	0	0.0	1.20	504.	0.0	-454.39	0.0	454.39	293.60	64.	0
1198	S	S	0	0.0	1.39	378.	0.0	-492.93	0.0	492.93	318.17	64.	0
1199	S	S	0	0.0	1.63	63.	0.0	-514.52	0.0	514.52	357.49	64.	0

Note rapid decrease of TH

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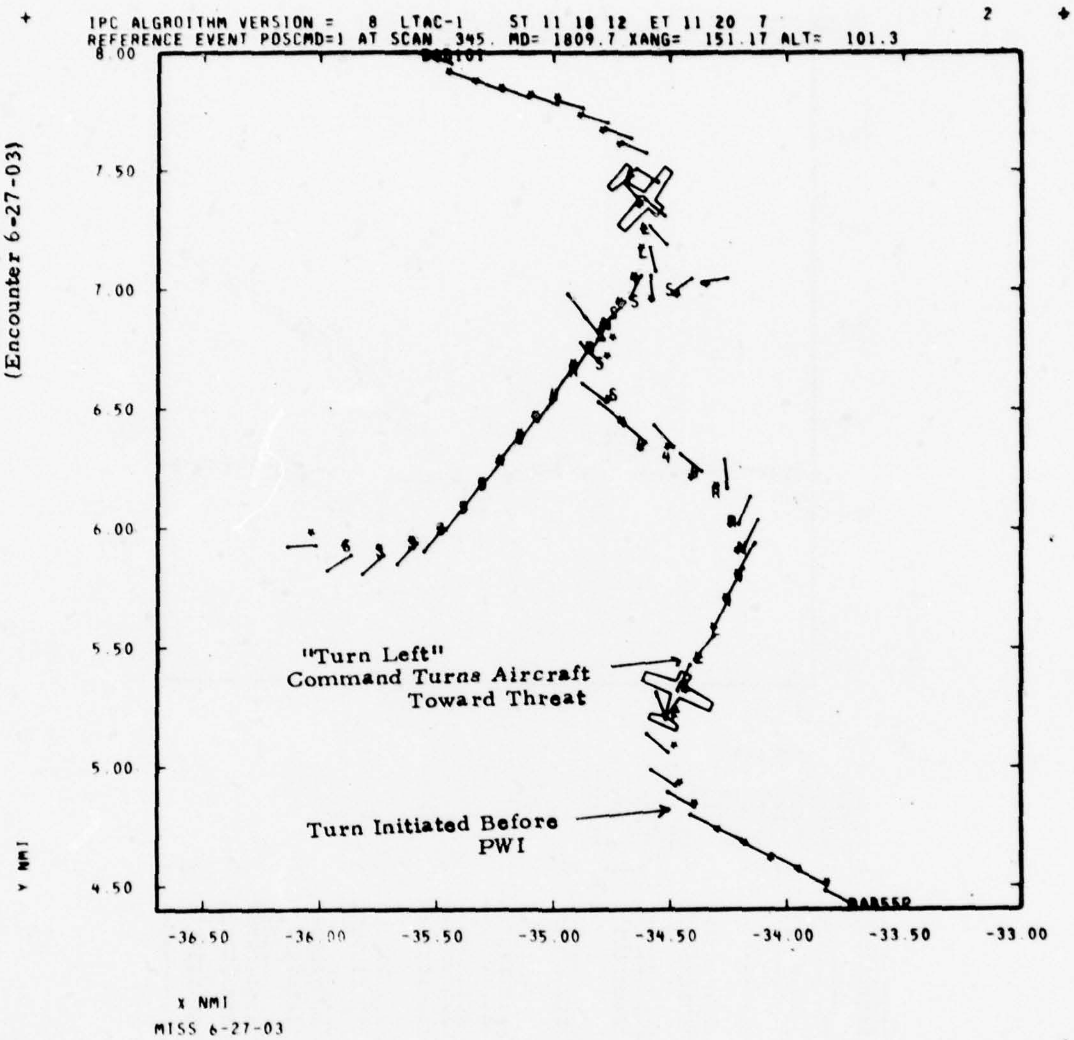
EXAMPLE 17
(Encounter 6-27-03)



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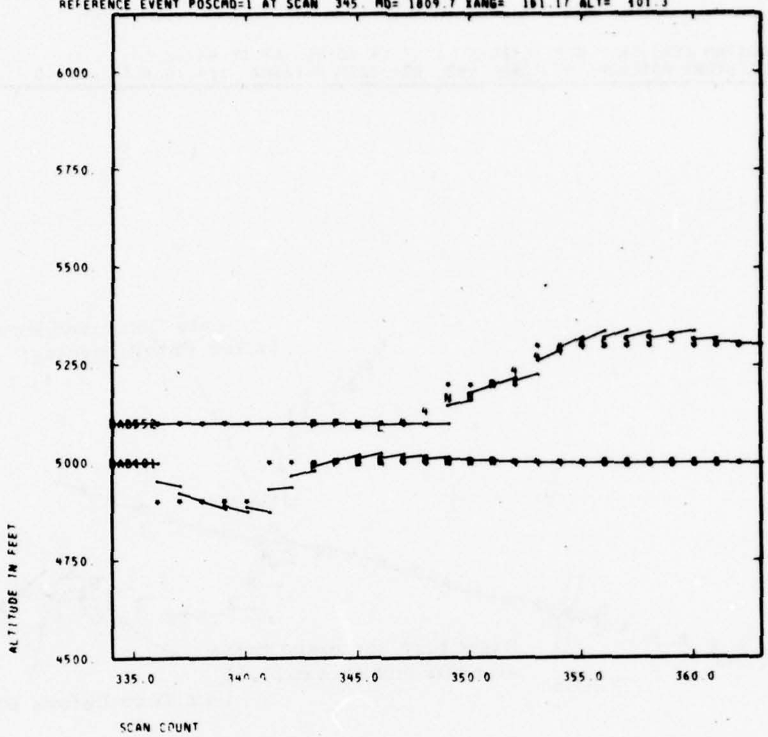
IPC ALGROITHM VERSION = 8 LTAC-1 ST 11 18 12 ET 11 20 7
REFERENCE EVENT POSCMD=1 AT SCAN 345. MD= 1809.7 XANG= 161.17 ALT= 101.3



IPC ALGORITHM VERSION = 8 LTAC-1
CPAH = 3195.910 CPAV = 85.816
CPA ON SCAN 354 SCPA = 3208.659 SCPAH = 3195.910 SCPAV = 285.750
AC1 TRACK = 1 ID = DAB552 IFR
AC2 TRACK = 3 ID = DAB101 IFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
343			0	71.95	2.57	12587.	38.2	-134.04	3.51	0.0	-317.42	64.	0
344	F	F	-2	50.02	2.31	8068.	26.3	-110.54	4.20	0.0	-364.38	64.	2
345	F	F	1	43.51	2.07	1428.	24.3	-96.45	3.96	0.0	-333.24	64.	2
346	L	L	1	38.34	1.83	1858.	27.4	-89.41	3.27	0.0	-289.08	64.	2
347	L	L	4	27.78	1.62	3383.	36.0	-87.16	2.42	0.0	-305.05	64.	2
348	L	L	4	26.95	1.40	5832.	54.1	-87.80	1.62	0.0	-225.12	64.	2
349	L	L	0	30.59	1.23	6388.	93.7	-89.90	0.96	28.50	-144.46	64.	2
350	NL	NL	1	27.90	1.10	5877.	-45.5	-138.88	-3.06	138.88	-118.90	64.	2
351	R	R	1	31.28	0.97	5514.	-36.5	-173.96	-4.76	173.96	-76.13	64.	2
352	R	R	4	22.59	0.83	4647.	-39.4	-196.48	-4.99	196.48	-66.54	64.	2
353	R	R	4	13.08	0.70	3592.	-47.5	-209.06	-4.40	209.06	-60.42	64.	2
354	R	R	4	9.37	0.60	3513.	-37.4	-260.90	-6.97	260.90	-27.12	64.	2
355	R	R	4	0.24	0.54	3207.	-40.1	-294.35	-7.34	294.35	-14.30	64.	2
356	R	R	0	0.0	0.55	3291.	0.0	-313.06	0.0	313.06	13.95	64.	0
357	S	S	0	0.0	0.63	3461.	0.0	-321.24	0.0	321.24	42.21	64.	0
358	S	S	0	0.0	0.83	3795.	0.0	-322.53	0.0	322.53	89.74	64.	0
359	S	S	0	0.0	1.05	4001.	0.0	-320.01	0.0	320.01	135.88	64.	0
360	S	S	0	0.0	1.20	4017.	0.0	-329.35	0.0	329.35	161.99	64.	0
361	S	S	0	0.0	1.56	3561.	0.0	-315.43	0.0	315.43	259.47	64.	0
362	S	S	0	0.0	1.76	709.	0.0	-309.27	0.0	309.27	345.24	64.	0

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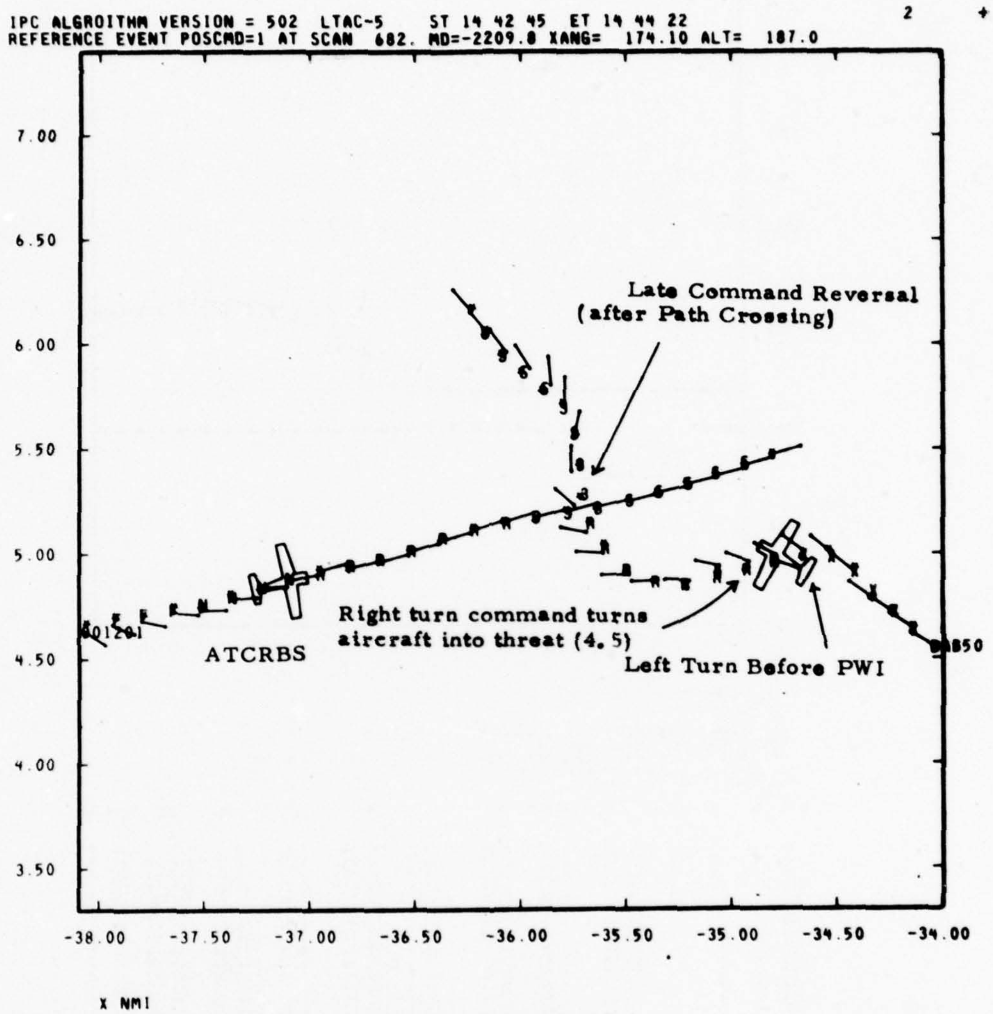
EXAMPLE 18
(Encounter 15-136-06)



MISS 15-136D JANUARY, 1977 DRONE DAB552 INT ATCRBS

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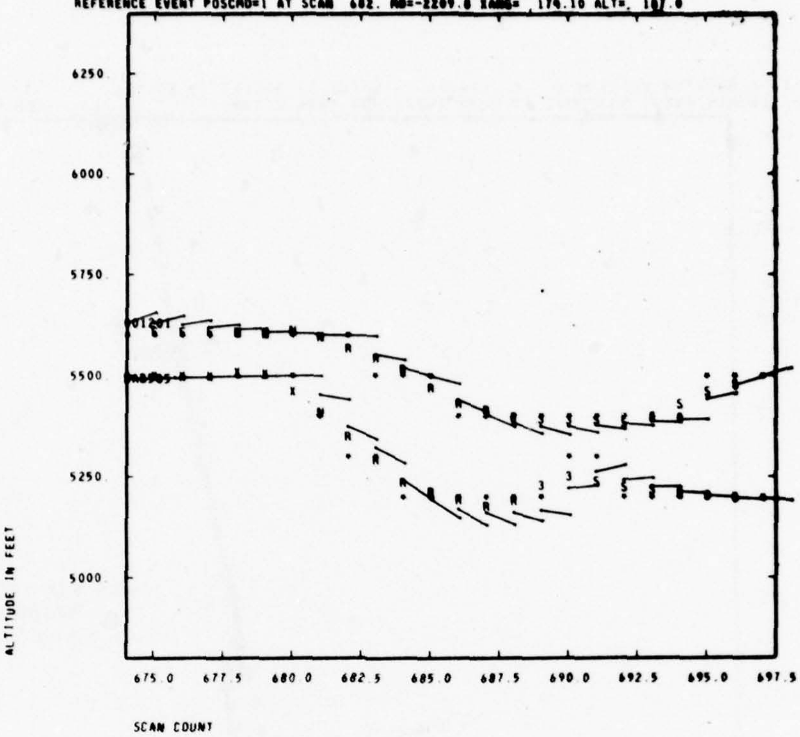
IPC ALGROITHM VERSION = 502 LTAC-5 ST 14 42 45 ET 14 44 22
REFERENCE EVENT POSCMD=1 AT SCAN 682. MD=-2209.0 XANG= 179.10 ALT= 107.0



IPC ALGORITHM VERSION = 502 LTAC-5
CPAH = 1469.268 CPAV = 97.910
CPA ON SCAN 690 SCPA = 1475.878 SCPAH = 1469.268 SCPAV = 139.523
AC1 TRACK = 3 ID = DAB505 IFR
AC2 TRACK = 19 ID = 001201 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
674	X	X	0	78.64	4.27	14226.	-13.6	128.27	9.40	128.27	-819.26	64.	0
675	X	X	0	73.91	4.04	12527.	-19.3	136.41	7.08	136.41	-779.07	64.	0
676	X	F	0	68.54	3.79	10742.	-28.1	135.53	4.82	135.53	-740.34	64.	0
677	X	F	-2	63.80	3.56	9262.	-44.6	129.94	2.91	129.94	-697.93	64.	2
678	X	F	0	58.65	3.32	7441.	-83.4	122.62	1.47	122.62	-657.78	64.	2
679	X	NL	0	55.42	3.10	7244.	-238.0	115.45	0.49	115.45	-605.30	64.	2
680	X	NL	0	50.34	2.85	6394.	971.6	109.38	-0.11	102.17	-560.38	64.	2
681	X	NL	0	44.14	2.59	4572.	251.3	104.77	-0.42	78.09	-522.51	64.	2
682	NL	NL	1	37.64	2.31	2490.	-51.0	148.02	2.90	148.02	-483.96	64.	2
683	R	R	1	31.46	2.03	516.	-29.4	225.09	7.67	225.09	-439.94	64.	2
684	R	R	1	25.88	1.76	410.	-40.4	230.80	5.71	230.80	-389.15	64.	2
685	R	R	1	20.30	1.47	1592.	-38.0	275.82	7.25	275.82	-331.12	64.	2
686	R	R	1	14.53	1.18	1936.	-43.1	303.43	7.03	303.43	-268.12	64.	2
687	R	R	1	8.64	0.90	1816.	-108.9	271.34	2.49	271.34	-203.80	64.	2
688	R	R	1	1.80	0.63	1176.	808.0	243.87	-0.30	224.55	-143.10	64.	2
689	R	R	3	-6.71	0.39	439.	127.2	222.87	-1.75	110.73	-88.97	64.	2
690	L	L	3	-27.72	0.19	549.	91.4	208.29	-2.28	62.36	-35.08	64.	2
691	L	L	0	95.22	0.19	1060.	27.1	152.89	-5.65	0.0	10.41	64.	0
692	S	S	0	18.49	0.35	1069.	17.4	115.59	-6.64	0.0	39.32	64.	0
693	S	S	0	1.97	0.54	1114.	49.9	139.74	-2.80	0.0	82.08	64.	0
694	S	S	0	-5.89	0.72	747.	471.7	161.36	-0.34	139.47	118.05	64.	0
695	S	S	0	-10.98	0.93	1452.	-174.1	178.52	1.03	178.52	178.09	64.	0
696	S	S	0	-16.02	1.16	1452.	-47.2	237.20	5.03	237.20	229.37	64.	0
697	S	S	0	-20.66	1.38	1577.	-43.1	277.71	6.45	277.71	276.62	64.	0

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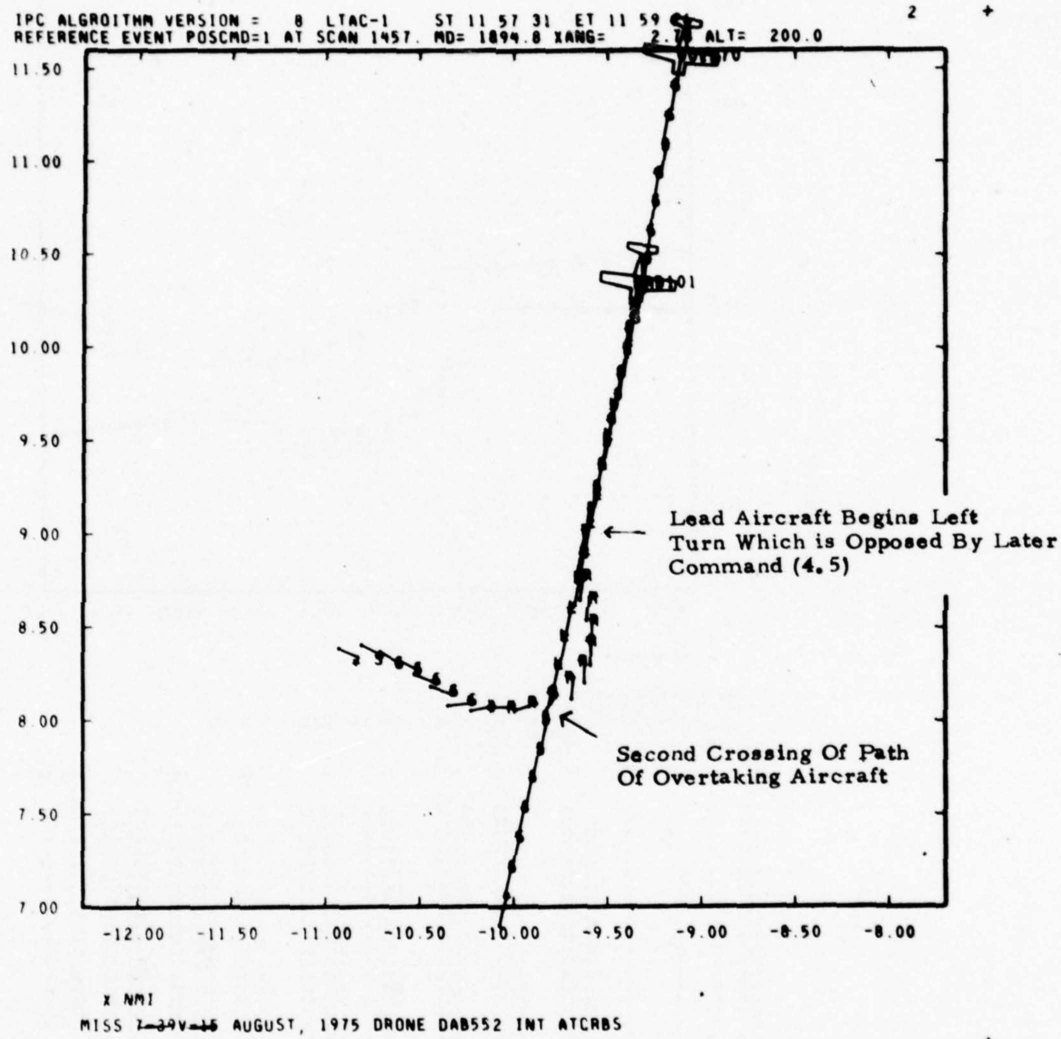
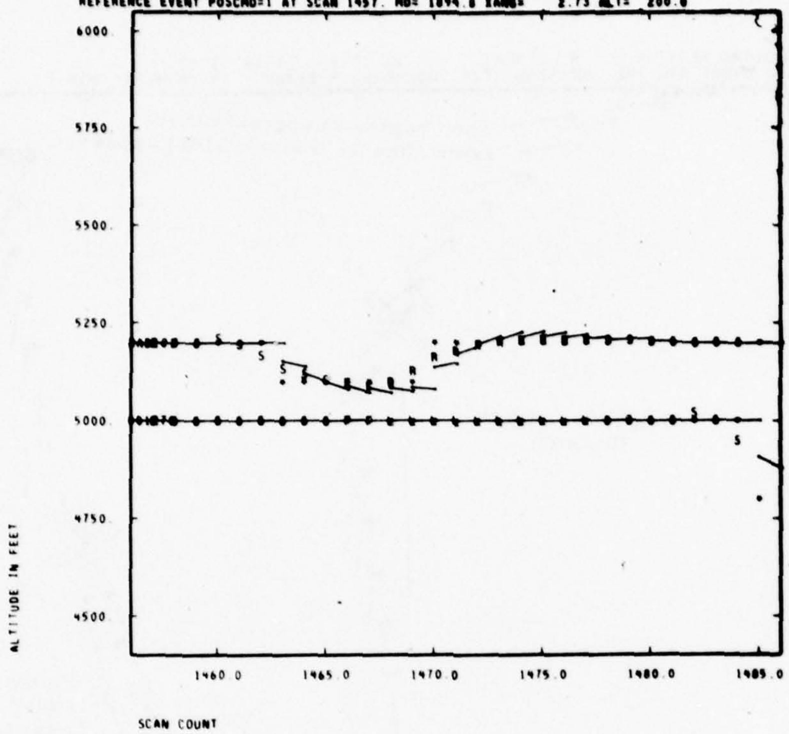
EXAMPLE 19
(Encounter 7-39-15)



IPC ALGROITHM VERSION = 8 LTAC-1   ST 11 57 31 ET 11 59 26
REFERENCE EVENT POSCMD=1 AT SCAN 1957. MD= 1899.8 XANG=   2.73 ALT= 200.0



IPC ALGORITHM VERSION =   8 LTAC-1
CPAH = 2035.804 CPAV =   85.301
CPA ON SCAN 1478 SCPA = 2046.198 SCPAH = 2035.804 SCPAV = 205.980
AC1 TRACK = 3 ID = DAB101   VFR
AC2 TRACK =133 ID = 001270   VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
1456	S	S	0	112.43	1.27	1066.	1045.3	-199.55	0.19	187.34	-41.19	64.	0
1457	S	S	0	111.17	1.24	856.	1352.0	-199.35	0.15	189.91	-38.75	64.	0
1458	S	S	0	101.90	1.19	721.	1939.2	-199.34	0.10	192.76	-38.27	64.	0
1459	S	S	0	99.21	1.16	658.	3114.8	-199.43	0.06	195.33	-36.59	64.	0
1460	S	S	0	90.27	1.12	315.	5875.2	-199.56	0.03	197.38	-36.36	64.	0
1461	S	S	0	84.62	1.09	532.	15206.9	-199.69	0.01	198.85	-35.44	64.	0
1462	S	S	0	81.96	1.06	147.	100.0	-199.81	0.0	199.74	-33.83	64.	0
1463	S	S	0	84.11	1.04	486.	-28564.2	-199.90	-0.01	199.90	-31.03	64.	0
1464	S	S	0	81.57	1.00	921.	41.9	-153.56	3.66	0.0	-29.21	64.	0
1465	S	S	0	75.81	0.97	1043.	23.7	-121.04	5.11	0.0	-28.00	64.	0
1466	S	S	0	65.82	0.93	1034.	19.5	-100.62	5.15	0.0	-27.82	64.	0
1467	F	F	-2	57.55	0.89	1040.	20.2	-89.46	4.43	0.0	-27.59	64.	2
1468	F	F	1	50.42	0.85	965.	24.9	-84.99	3.41	0.0	-27.04	64.	2
1469	R	L	1	42.38	0.81	469.	35.7	-84.71	2.37	0.0	-26.63	64.	2
1470	R	L	1	36.22	0.78	610.	58.6	-86.73	1.48	0.0	-25.60	64.	2
1471	R	L	1	24.20	0.72	1778.	-47.9	-136.14	-2.84	136.14	-25.33	64.	2
1472	R	L	1	16.18	0.68	2291.	-35.9	-171.75	-4.78	171.75	-24.03	64.	2
1473	R	L	1	11.50	0.64	2417.	-38.1	-194.99	-5.12	194.99	-22.13	64.	2
1474	R	L	1	3.21	0.60	2110.	-45.6	-208.04	-4.57	208.04	-21.13	64.	2
1475	R	L	1	-7.21	0.54	1214.	-59.2	-213.88	-3.61	213.88	-21.22	64.	2
1476	R	L	1	-14.75	0.48	1612.	-83.2	-215.10	-2.59	215.10	-24.73	64.	2
1477	R	L	1	-19.69	0.40	1981.	-128.3	-213.58	-1.66	213.58	-30.41	64.	2
1478	R	L	3	-49.55	0.34	1954.	-227.0	-210.79	-0.93	210.79	-15.96	64.	2
1479	R	L	0	0.0	0.33	1914.	0.0	-207.75	0.0	207.75	13.24	64.	0
1480	S	S	0	0.0	0.41	1848.	0.0	-209.32	0.0	209.32	41.89	64.	0
1481	S	S	0	0.0	0.55	2011.	0.0	-204.35	0.0	204.35	82.43	64.	0
1482	S	S	0	0.0	0.73	1921.	0.0	-201.41	0.0	201.41	128.91	64.	0
1483	S	S	0	0.0	0.93	1902.	0.0	-199.70	0.0	199.70	177.22	64.	0
1484	S	S	0	0.0	1.13	1971.	0.0	-198.82	0.0	198.82	218.59	64.	0
1485	S	S	0	0.0	1.33	2028.	0.0	-198.52	0.0	198.52	258.95	64.	0

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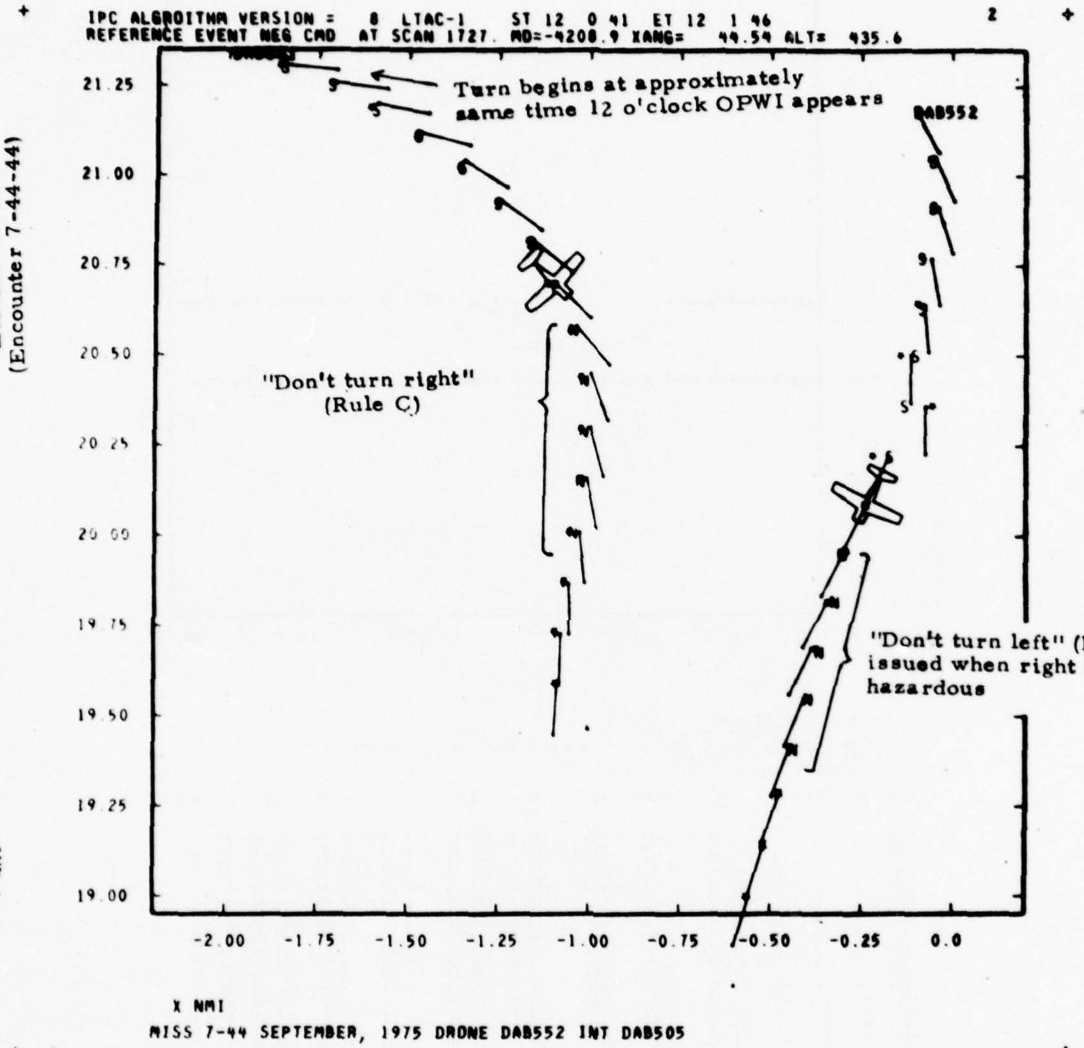
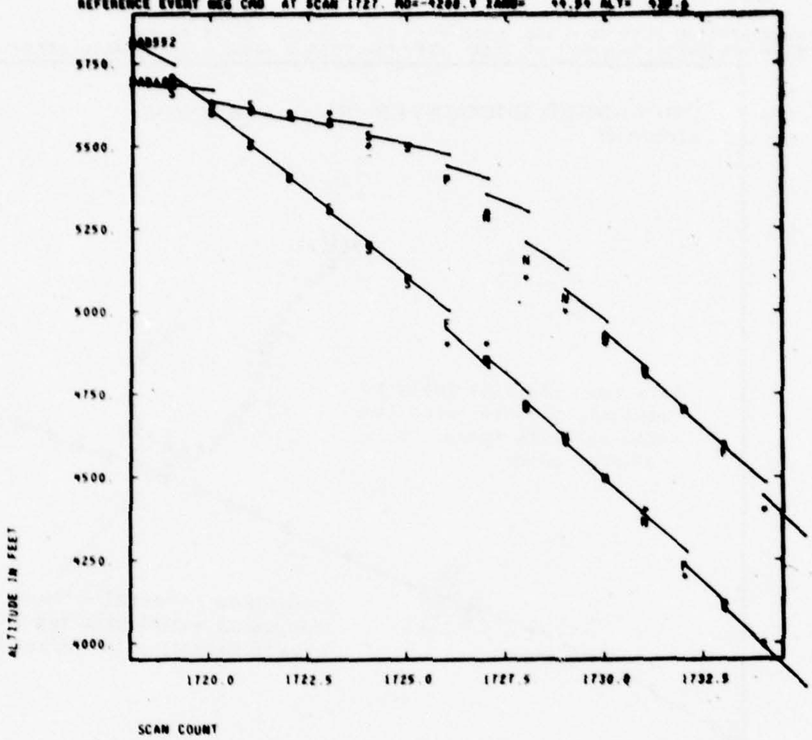
EXAMPLE 20
(Encounter 7-44-44)



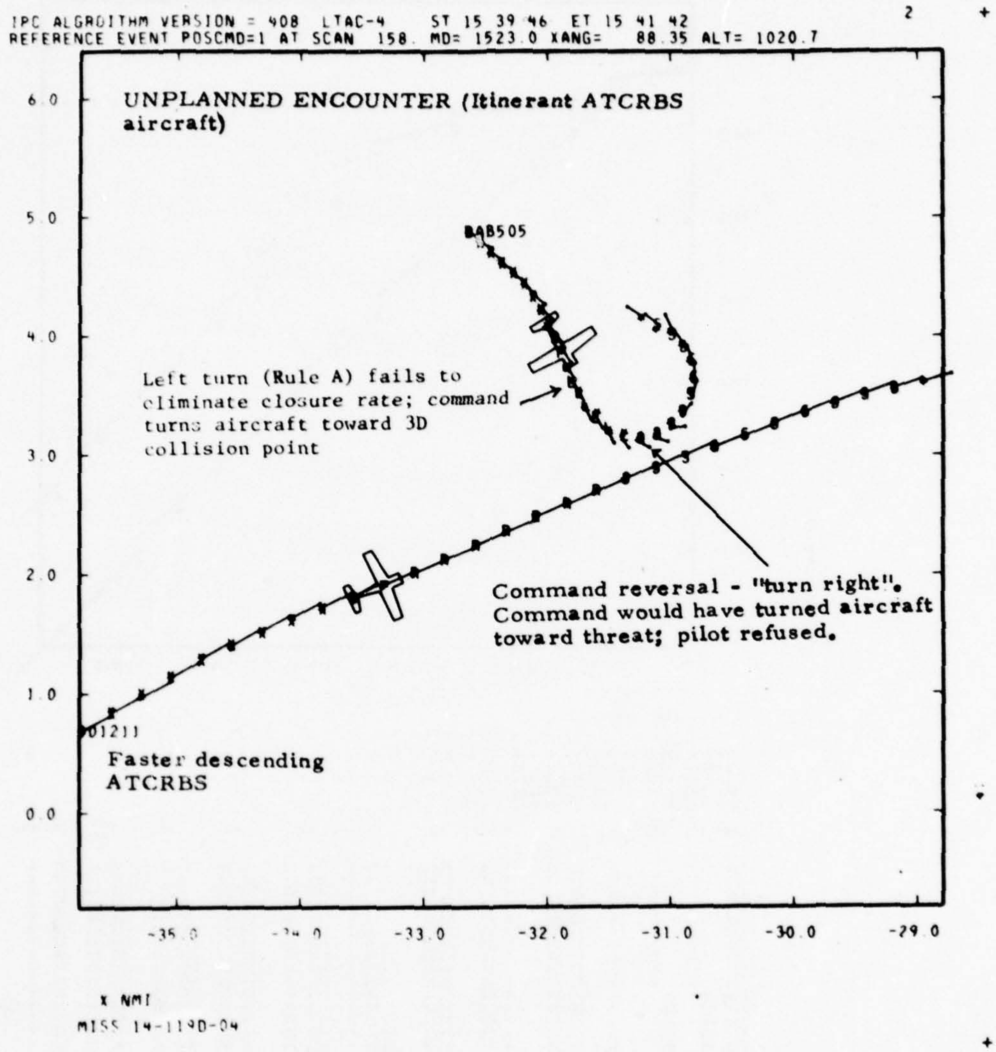
IPC ALGORITHM VERSION = 8 LTAC-1 ST 12 0 41 ET 12 1 46
REFERENCE EVENT NEG CMD AT SCAN 1727. MD=-9200.9 XAMD= 44.54 ALT= 428.6



IPC ALGORITHM VERSION = 8 LTAC-1
CPAH = 4846.109 CPAV = 19.203
CPA ON SCAN 1734 SCPA = 4863.008 SCPAH = 4846.109 SCPAV = 405.055
AC1 TRACK = 1 ID = DAB601 VFR
AC2 TRACK = 3 ID = DAB552 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
1718			0	60.21	1.96	7443.	-35.7	186.12	5.22	186.12	-212.62	32.	0
1719	S	S	0	83.42	1.89	9163.	9.8	120.61	-12.29	0.0	-159.37	32.	0
1720	S	S	0	80.68	1.81	9109.	1.5	26.89	-17.76	0.0	-131.96	32.	0
1721	S	S	0	72.00	1.71	8626.	-1.6	-27.82	-16.90	27.82	-128.96	32.	0
1722	S	S	0	63.26	1.59	8016.	-5.8	-99.04	-17.19	99.04	-126.08	32.	0
1723	S	S	0	56.58	1.47	7363.	-10.0	-183.18	-18.30	183.18	-117.60	32.	0
1724	S	S	0	51.08	1.39	6179.	-14.0	-277.32	-19.80	277.32	-104.39	32.	0
1725	S	S	0	53.84	1.30	6083.	-18.7	-330.59	-17.68	330.59	-92.08	32.	0
1726	S	S	-2	27.78	1.15	4693.	-22.7	-401.32	-17.66	401.32	-129.46	32.	2
1727	F	F	0	25.57	1.05	4522.	-24.8	-491.48	-19.82	491.48	-110.20	32.	2
1728	NR	NL	0	23.54	0.96	4319.	-35.9	-492.06	-13.71	492.06	-91.52	32.	2
1729	NR	NL	0	26.76	0.90	3809.	-56.5	-478.95	-8.48	478.95	-65.26	32.	2
1730	NR	NL	0	27.50	0.87	3567.	-103.2	-460.81	-4.47	460.81	-55.51	32.	2
1731	NR	NL	0	31.12	0.85	3412.	-266.5	-442.28	-1.66	442.28	-45.78	32.	2
1732	NR	NL	0	35.35	0.84	3168.	5669.4	-426.28	0.08	423.87	-37.17	32.	0
1733	F	F	0	41.23	0.82	2885.	-180.1	-460.32	-2.56	460.32	-29.69	32.	0
1734	F	F	0	52.64	0.82	2841.	-134.4	-484.27	-3.60	484.27	-22.61	32.	0

EXAMPLE 21
(Encounter 14-119-04)



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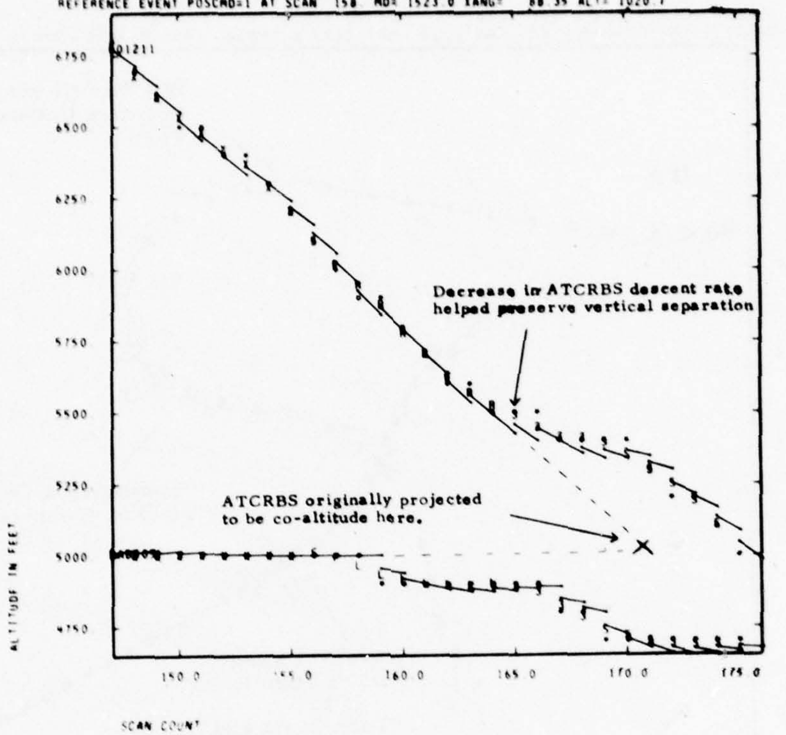
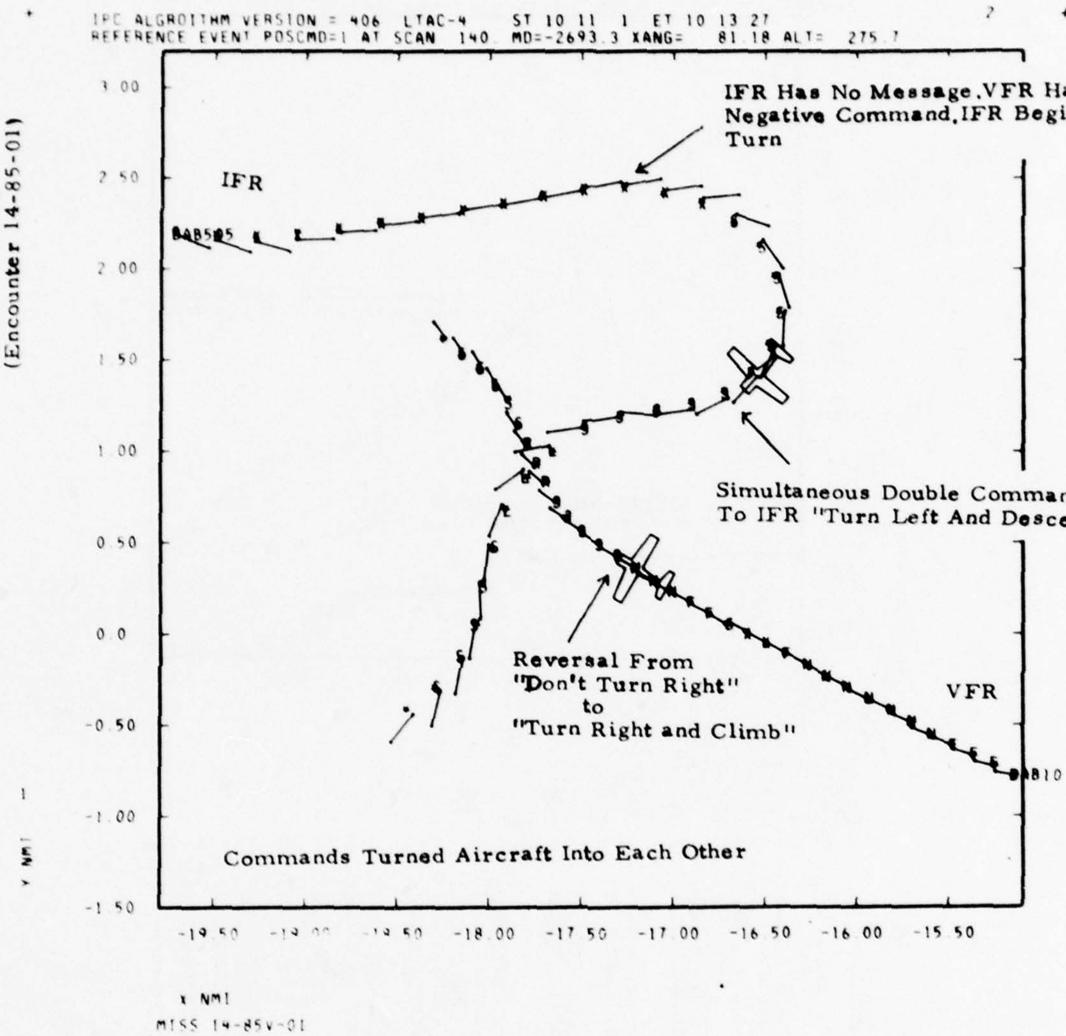
IPC ALGROITHM VERSION = 408 LTAC-4 ST 15 39 46 ET 15 41 42
REFERENCE EVENT POSCMD=1 AT SCAN 158 MD= 1523.0 XANG= 88.35 ALT= 1020.7



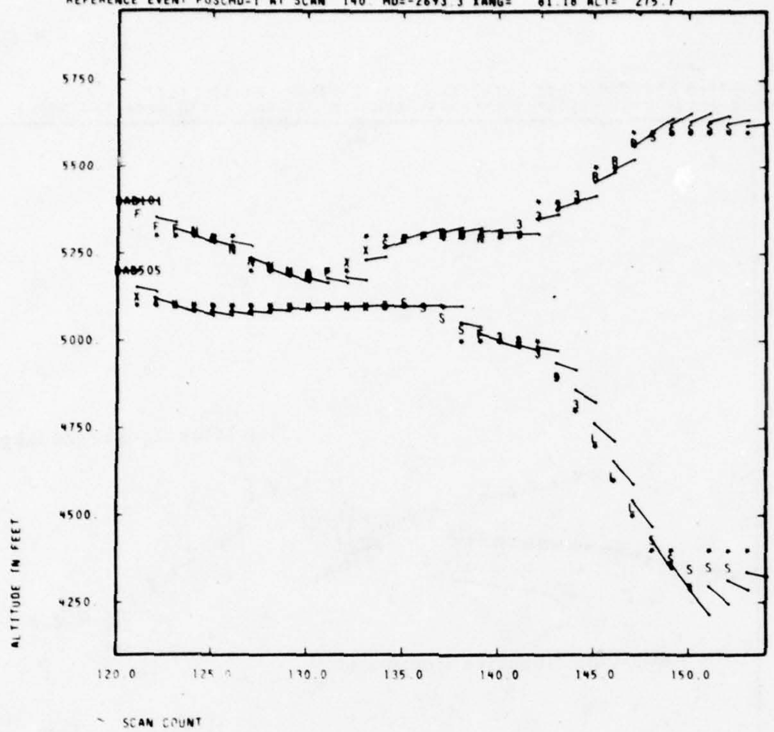
IPC ALGORITHM VERSION = 408 LTAC-4
CPAH = 1733.267 CPAV = 303.086
CPA ON SCAN 166 SCPA = 1826.633 SCPAH = 1733.267 SCPAV = 576.520
AC1 TRACK = 2 ID = DABS05 VFR
AC2 TRACK = 75 ID = 001211 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
147	X	X	0	91.84	5.49	14	88.5	1823.46	-20.61	421.93	-1155.94	68	0
148	X	X	0	87.69	5.23	34	95.7	1766.61	-18.95	511.69	-1100.69	68	0
149	X	X	0	81.66	4.96	192	93.6	1694.54	-18.10	463.61	-1059.08	68	0
150	X	X	0	75.78	4.69	552	85.8	1610.32	-18.77	334.17	-1018.17	68	0
151	X	X	0	68.80	4.40	1085	76.3	1517.29	-19.88	165.16	-982.55	68	0
152	X	X	0	62.45	4.12	1570	83.1	1464.91	-17.62	266.81	-941.79	68	0
153	X	X	0	58.00	3.86	1458	80.5	1395.52	-17.33	217.16	-888.06	68	0
154	X	X	0	53.25	3.59	1157	92.6	1358.94	-14.68	360.80	-831.55	68	0
155	X	X	0	47.50	3.29	778	88.9	1298.84	-14.60	305.83	-777.38	68	0
156	X	X	0	42.04	3.00	293	76.7	1220.41	-15.92	137.80	-720.66	68	0
157	S	S	-2	37.68	2.73	407	63.4	1129.04	-17.80	0.0	-657.72	68	2
158	F	F	1	32.62	2.44	786	52.3	1029.48	-19.70	0.0	-593.08	68	2
159	L	R	1	27.38	2.14	1055	43.4	925.46	-21.34	0.0	-526.71	68	2
160	L	R	1	21.80	1.83	1225	58.1	912.44	-15.69	0.0	-457.70	68	2
161	L	R	1	16.76	1.54	1360	62.9	871.67	-13.86	0.0	-386.88	68	2
162	L	R	1	11.04	1.24	1317	56.3	807.46	-14.34	0.0	-312.78	68	2
163	L	R	1	5.64	0.98	1200	45.4	725.62	-16.00	0.0	-242.92	68	2
164	L	R	1	-1.65	0.71	937	46.5	678.05	-14.58	0.0	-172.95	68	2
165	L	R	3	-9.92	0.51	855	40.1	609.32	-15.18	0.0	-116.34	68	2
166	R	L	3	-29.65	0.33	795	42.9	571.15	-13.32	0.0	-56.45	68	2
167	R	L	3	-58.63	0.25	985	53.3	554.83	-10.40	0.0	-31.33	68	2
168	R	L	3	-181.38	0.25	1507	75.3	552.59	-7.34	53.39	-10.00	68	2
169	R	L	0	41.57	0.37	1551	120.2	558.21	-4.64	242.48	37.21	68	0
170	S	S	0	12.26	0.53	1471	-665.0	613.64	0.92	613.64	85.06	68	0
171	S	S	0	1.15	0.73	1357	-173.6	655.75	3.78	655.75	149.24	68	0
172	S	S	0	-5.90	1.00	1599	-489.2	638.30	1.30	638.30	243.03	68	0
173	S	S	0	-10.92	1.30	2166	157.3	577.03	-3.67	327.53	360.69	68	0
174	S	S	0	-17.17	1.64	1496	91.8	533.10	-5.81	138.23	436.13	68	0
175	S	S	0	-20.05	1.98	2747	47.9	458.40	-9.58	0.0	598.43	68	0

EXAMPLE 22
(Encounter 14-85-01)



IPC ALGORITHM VERSION = 406 LTAC-4 ST 10 11 1 ET 10 13 27
REFERENCE EVENT POSCMD=1 AT SCAN 140 MD=-2693.3 XANG= 81.18 ALT= 275.7



IPC ALGORITHM VERSION = 406 LTAC-4
CPAH = 574.649 CPAV = 87.559
CPA ON SCAN 146 SCPA = 1071.138 SCPAH = 574.649 SCPAV = 903.945
AC1 TRACK = 2 ID = DAB505 IFR
AC2 TRACK = 1 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
120	X	X	0	77.77	5.79	7644.	7372.1	-199.57	0.03	197.73	-1535.99	68.	0
121	X	X	0	72.96	5.47	8132.	21887.2	-199.70	0.01	199.08	-1455.11	68.	0
122	X	F	0	68.60	5.14	8730.	-75.5	-246.22	-3.26	246.22	-1366.32	68.	0
123	X	F	-2	65.14	4.83	9555.	-181.0	-232.50	-1.28	232.50	-1267.76	68.	2
124	X	F	0	67.64	4.53	14018.	-5408.2	-220.46	-0.04	220.46	-1071.06	68.	2
125	X	NR	0	65.96	4.26	14637.	334.1	-211.06	0.63	168.11	-967.37	68.	2
126	X	NR	0	64.24	3.99	14949.	227.1	-204.43	0.90	143.21	-866.96	68.	2
127	X	NR	0	62.90	3.72	15085.	218.9	-200.24	0.91	138.02	-769.42	68.	2
128	X	NR	0	62.85	3.48	15260.	37.4	-151.56	4.05	0.0	-670.37	68.	2
129	X	NR	0	63.36	3.25	15205.	22.9	-117.99	5.14	0.0	-576.25	68.	2
130	X	NR	0	66.86	3.06	15281.	19.6	-97.50	4.99	0.0	-480.20	68.	2
131	X	NR	0	74.24	2.89	15363.	20.7	-86.84	4.19	0.0	-383.66	68.	0
132	X	F	0	85.48	2.72	15213.	26.3	-83.03	3.15	0.0	-294.59	68.	0
133	X	X	0	99.43	2.56	14732.	38.9	-83.43	2.15	0.0	-221.46	68.	0
134	X	X	0	121.99	2.40	14153.	-67.6	-132.43	-1.96	132.43	-157.95	68.	0
135	S	S	0	72.24	2.25	12666.	-43.4	-168.43	-3.88	168.43	-232.07	68.	0
136	S	F	-2	41.99	2.07	10006.	-44.2	-192.29	-4.35	192.29	-333.86	68.	2
137	S	F	0	34.67	1.87	8302.	-51.9	-206.16	-3.97	206.16	-320.86	68.	2
138	S	NR	0	28.96	1.66	6570.	-66.5	-212.73	-3.20	212.73	-293.46	68.	2
139	S	NR	0	24.13	1.45	4465.	-46.7	-260.82	-5.58	260.82	-256.04	68.	2
140	F	NR	3	20.02	1.24	2734.	-48.2	-292.20	-6.06	292.20	-207.80	68.	2
141	L D	R C	3	17.45	1.06	521.	-57.0	-310.18	-5.44	310.18	-152.38	68.	2
142	L D	R C	3	15.13	0.90	1519.	-73.6	-318.35	-4.33	318.35	-99.43	68.	2
143	L D	R C	3	11.04	0.76	2719.	-57.7	-366.48	-6.36	366.48	-61.16	68.	2
144	L D	R C	3	0.48	0.63	1535.	-45.3	-443.49	-9.79	443.49	-70.05	68.	2
145	L D	R C	0	-13.89	0.45	1394.	-40.0	-539.28	-13.49	539.28	-48.27	68.	2
146	LNC	RND	0	-52.30	0.22	836.	-34.5	-692.18	-20.05	692.18	-22.73	68.	2
147	LNC	RND	0	-129.59	0.06	305.	-34.9	-836.11	-23.93	836.11	-10.00	68.	2
148	LNC	RND	0	12.25	0.34	736.	-34.9	-1015.20	-29.09	1015.20	73.14	68.	0
149	S	S	0	-1.41	0.66	1417.	-37.8	-1169.75	-30.93	1169.75	154.11	68.	0
150	S	S	0	-8.81	1.00	2110.	-45.8	-1257.22	-27.46	1257.22	246.35	68.	0
151	S	S	0	-13.95	1.31	1082.	-53.9	-1341.93	-24.90	1341.93	337.29	68.	0
152	S	S	0	-18.66	1.60	1151.	-80.0	-1334.97	-16.68	1334.97	414.46	68.	0
153	S	S	0	-23.29	1.86	1223.	-132.7	-1311.89	-9.89	1311.89	470.30	68.	0

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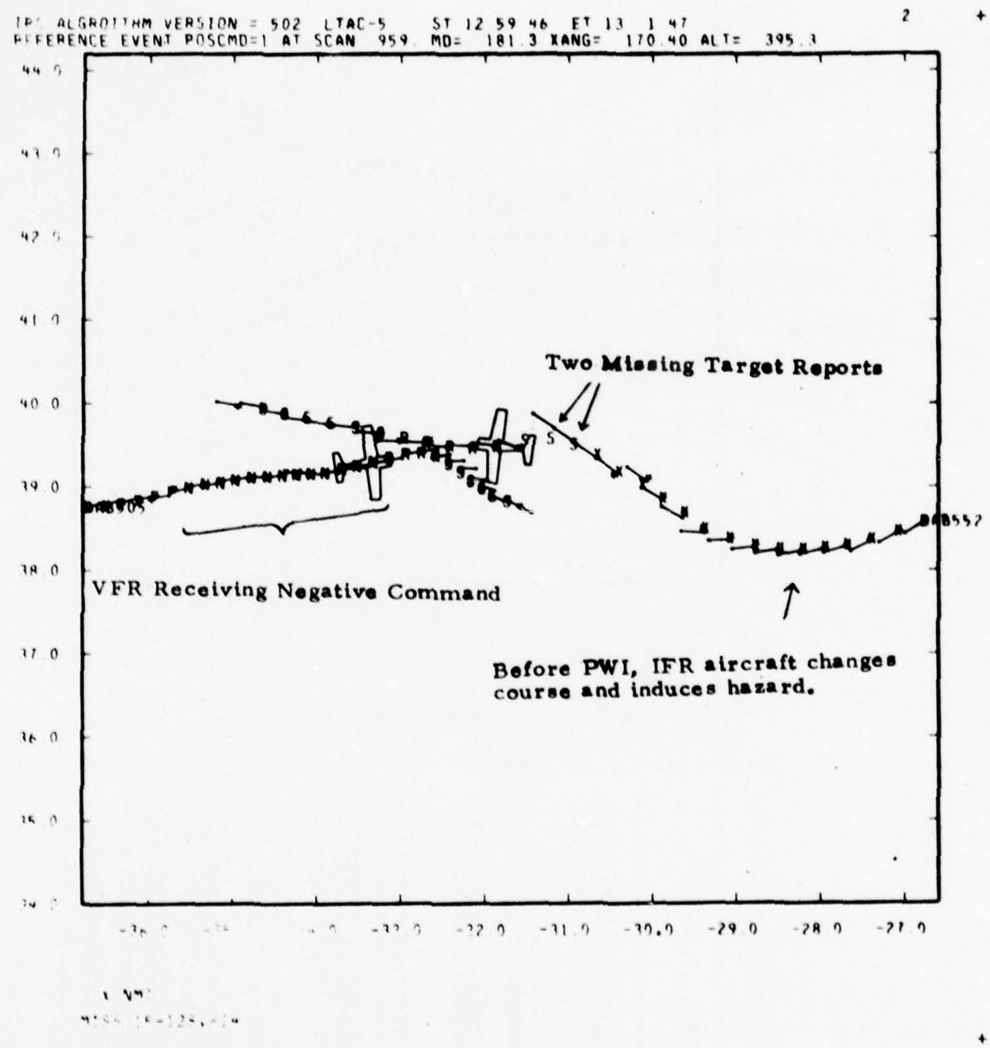
EXAMPLE 23
(Encounter 15-128-04)



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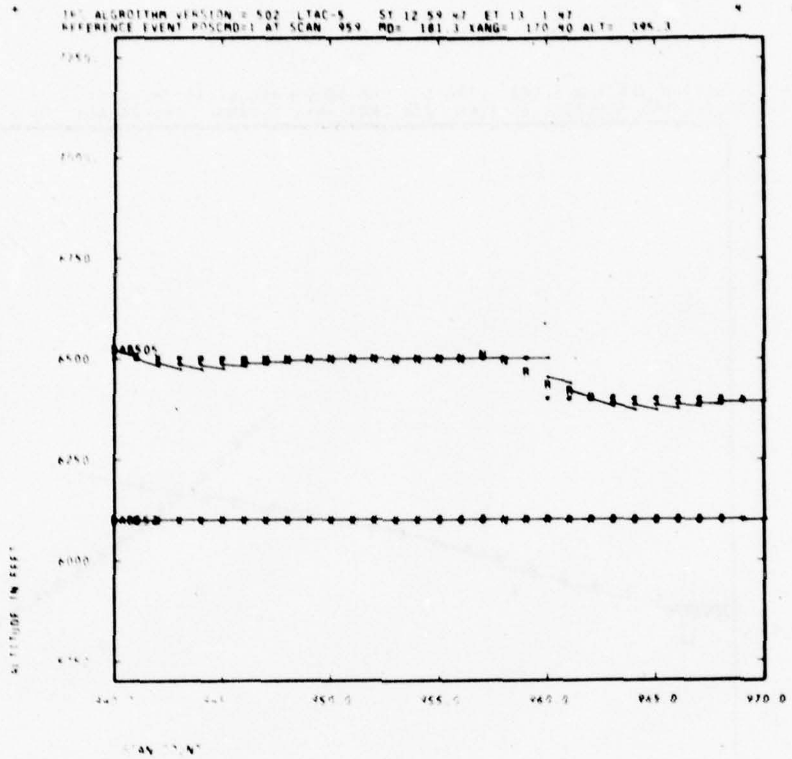
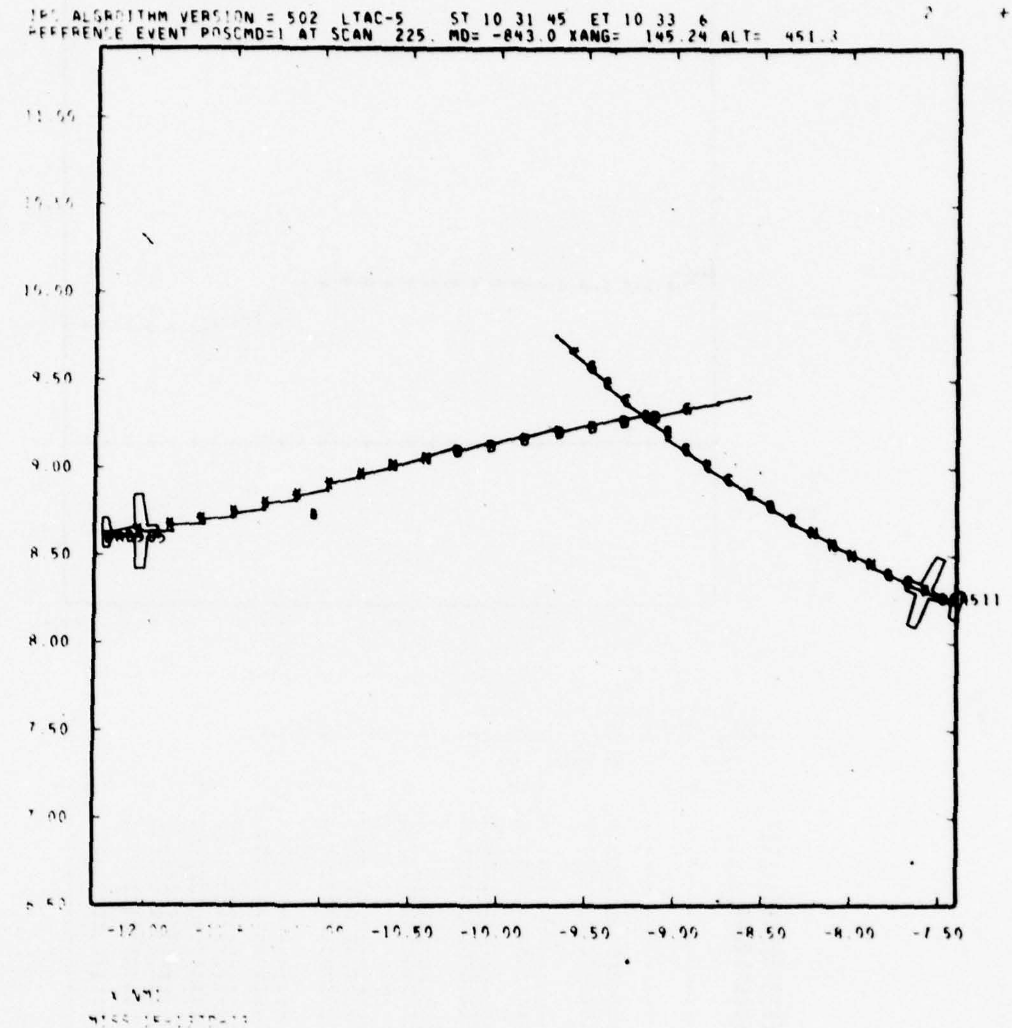


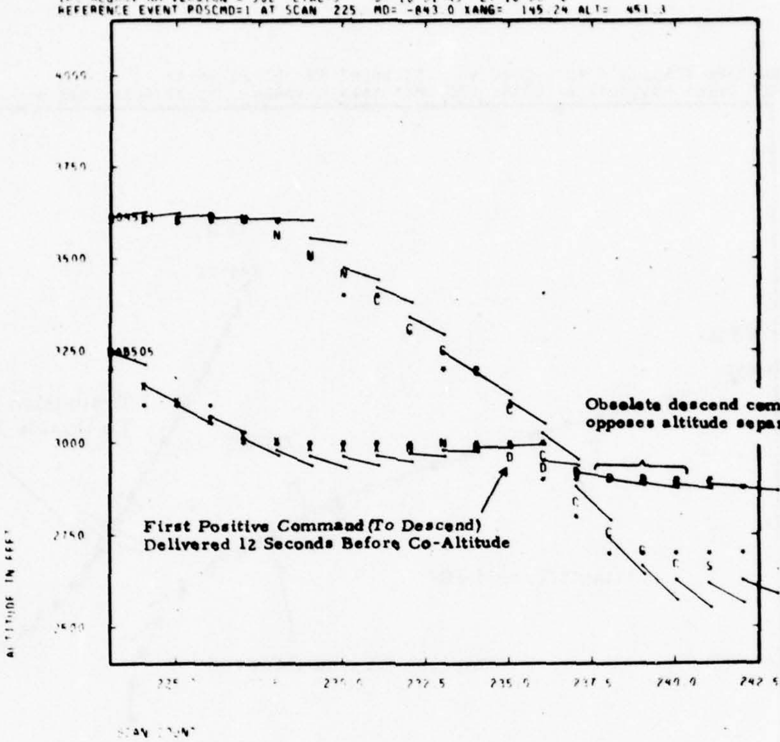
TRC ALGORITHM VERSION = 502 LTAC-5
CPAH = 881.188 CPAV = 294.109
CPA ON SCAN 961 SCPA = 437.473 SCPAH = 881.188 SCPAV = 319.441
AC1 TRACK = 3 ID = DABS05 VFR
AC2 TRACK = 2 ID = DABS52 IFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
940			0	90.69	10.43	15987	140.9	457.10	-3.24	236.52	-4288.64	68	0
941	X	X	0	92.51	9.97	27823	89.1	423.37	-4.75	100.14	-3834.89	68	0
942	X	X	0	84.92	9.47	24787	82.4	401.93	-4.88	70.23	-3768.25	68	0
943	X	X	0	77.56	8.95	22080	92.0	390.13	-4.24	101.66	-3675.41	68	0
944	X	X	0	69.49	8.45	15651	117.1	385.23	-3.29	161.48	-3655.32	68	0
945	F	X	-2	66.39	8.01	13559	166.9	384.75	-2.31	227.98	-3437.79	68	2
946	F	X	0	62.33	7.52	12725	267.5	386.68	-1.45	288.39	-3216.83	68	2
947	NR	X	0	59.15	7.06	11453	501.1	389.63	-0.78	336.76	-2984.58	68	2
948	NR	X	0	55.98	6.60	9630	1277.1	392.71	-0.31	371.80	-2754.90	68	2
949	NR	X	0	51.79	6.11	7681	36416.1	395.41	-0.01	394.67	-2543.97	68	2
950	NR	X	0	47.09	5.61	5064	-2660.8	397.51	0.15	397.51	-2347.69	68	2
951	NR	X	0	45.81	5.17	4219	-1865.6	399.00	0.21	399.00	-2043.78	68	2
952	NR	X	0	42.22	4.73	6452	-1837.4	399.94	0.22	399.94	-1841.11	68	2
953	NR	X	0	38.99	4.31	7923	-2125.7	400.45	0.19	400.45	-1638.20	68	2
954	NR	X	0	33.98	3.81	7729	-2751.3	400.66	0.15	400.66	-1459.40	68	2
955	NR	X	0	31.07	3.41	8303	-3940.4	400.68	0.10	400.68	-1253.30	68	2
956	NR	S	0	27.49	2.98	8307	-6301.2	400.59	0.06	400.59	-1061.66	68	2
957	NR	S	0	23.68	2.56	8092	-11771.3	400.46	0.03	400.46	-876.66	68	2
958	NR	S	0	14.31	1.95	3419	-10028.6	400.32	0.01	400.32	-761.93	68	2
959	NR	NR	1	8.81	1.49	1521	100.0	400.20	0.0	400.20	-603.77	68	2
960	R	R	1	2.80	1.03	896	61418.8	400.11	-0.01	399.66	-416.94	68	2
961	R	R	1	-7.86	0.53	404	102.1	353.64	-3.46	118.19	-219.47	68	2
962	R	R	1	-78.40	0.14	700	66.6	321.03	-4.82	0.0	-37.36	68	2
963	R	R	0	11.98	0.44	1123	61.9	300.50	-4.85	0.0	161.51	68	0
964	S	S	0	-0.82	0.89	1799	69.4	289.45	-4.17	5.79	336.74	68	0
965	S	S	0	-7.78	1.35	2183	88.9	285.07	-3.21	66.99	517.81	68	0
966	S	S	0	-13.20	1.81	2231	127.9	284.82	-2.23	133.45	700.89	68	0
967	S	S	0	-17.98	2.25	2041	207.7	286.89	-1.38	192.96	872.63	68	0
968	S	S	0	-22.58	2.67	1738	397.3	289.89	-0.73	240.27	1029.76	68	0
969	S	S	0	-27.14	3.11	1269	1063.8	292.95	-0.28	274.22	1193.28	68	0



EXAMPLE 24
(Encounter 15-137-03)

IPC ALGORITHM VERSION = 502 LTAC-5 ST 10 31 45 ET 10 33 6
REFERENCE EVENT POSCMD=1 AT SCAN 225 MD= -843.0 XANG= 145.24 ALT= 451.3



IPC ALGORITHM VERSION = 502 LTAC-5
CPAH = 748.735 CPAV = 33.481
CPA ON SCAN 239 SCPA = 773.179 SCPAH = 748.735 SCPAV = 192.881
AC1 TRACK = 1 ID = DAB505 IFR
AC2 TRACK = 25 ID = 004511 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
223	X	F	0	65.45	5.04	1852.	-29.3	294.98	10.07	294.98	-1373.76	64.	0
224	X	F	-2	63.83	4.76	1926.	-30.1	366.53	12.20	366.53	-1254.84	64.	2
225	X	F	1	61.55	4.47	1561.	-30.4	456.11	14.98	456.11	-1148.62	64.	2
226	X	C	1	58.91	4.19	1111.	-35.6	510.43	14.32	510.43	-1052.29	64.	2
227	X	C	0	55.92	3.91	653.	-45.2	538.05	11.90	538.05	-963.98	64.	2
228.	X	ND	0	52.32	3.63	226.	-48.3	593.78	12.30	593.78	-883.53	64.	2
229	X	ND	0	48.19	3.34	249.	-58.2	624.54	10.74	624.54	-809.18	64.	2
230	X	ND	0	44.12	3.06	404.	-119.6	591.10	4.94	591.10	-737.25	64.	2
231	X	ND	1	39.30	2.77	927.	224.8	513.65	-2.29	367.41	-668.50	64.	2
232	X	C	1	34.29	2.47	879.	78.2	455.77	-5.83	82.68	-601.07	64.	2
233	NC	C	1	29.26	2.17	857.	35.9	370.32	-10.30	0.0	-532.84	64.	2
234	NC	C	1	23.81	1.85	742.	18.3	268.00	-14.63	0.0	-462.87	64.	2
235	D	C	1	18.55	1.55	423.	13.7	203.38	-14.84	0.0	-391.29	64.	2
236	D	C	1	13.07	1.24	135.	7.5	121.83	-16.23	0.0	-316.92	64.	2
237	D	C	1	7.06	0.93	113.	5.1	74.96	-14.64	0.0	-239.80	64.	2
238	D	C	1	-0.46	0.62	364.	-2.1	-39.37	-18.50	39.37	-160.06	64.	2
239	D	C	1	-13.89	0.31	498.	-7.3	-155.77	-21.31	155.77	-79.55	64.	2
240	D	C	1	-142.43	0.11	665.	-11.4	-224.47	-19.75	224.47	-10.00	64.	2
241	D	C	0	13.89	0.32	806.	-16.0	-257.82	-16.07	257.82	77.34	64.	0
242	S	S	0	1.10	0.59	813.	-22.7	-267.36	-11.79	267.36	148.94	64.	0

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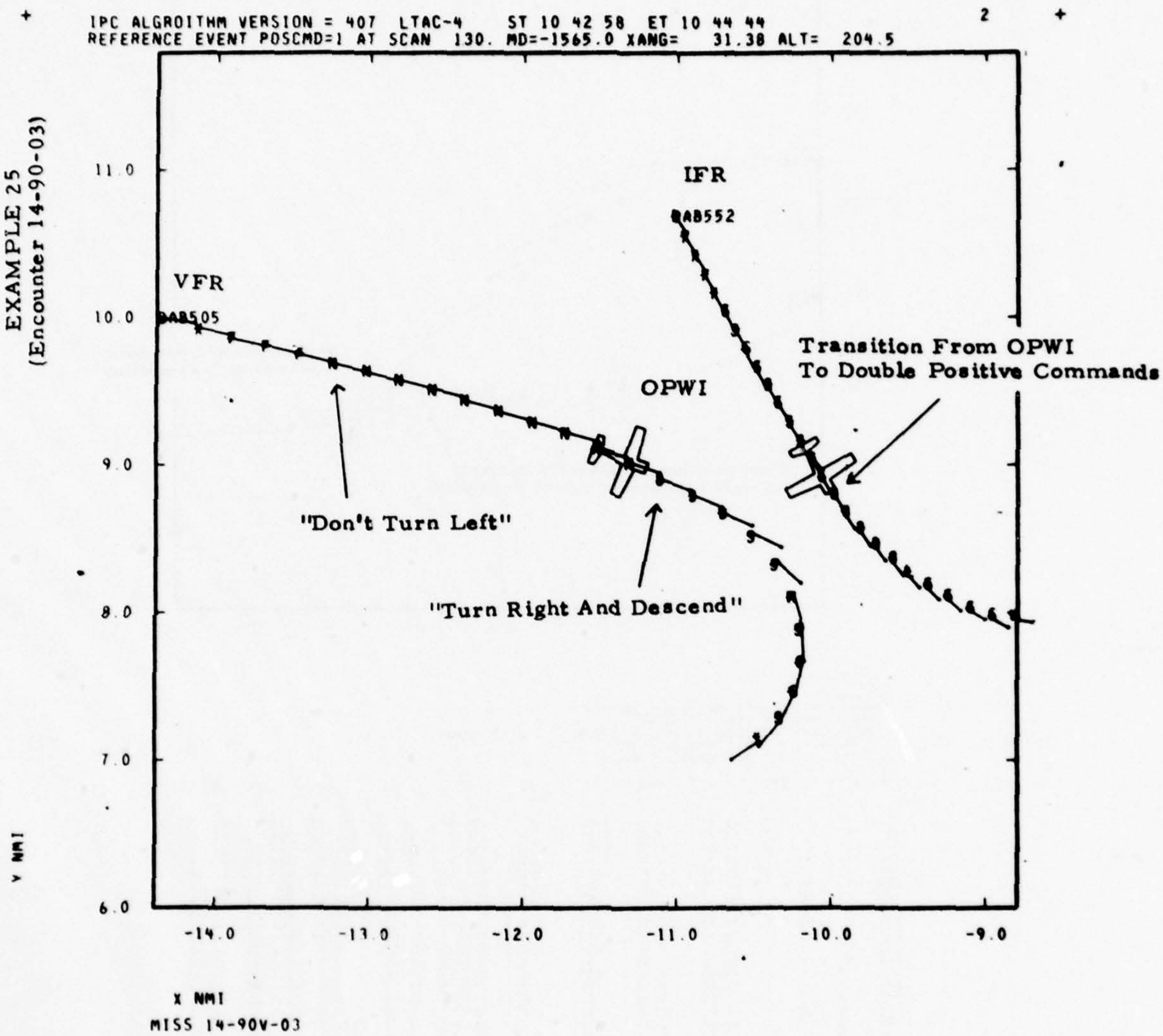
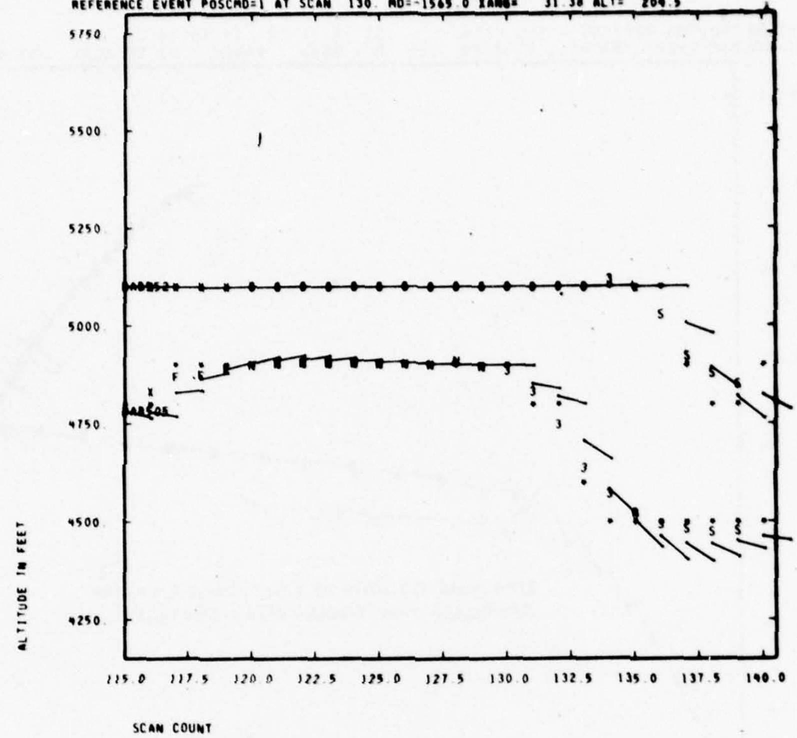


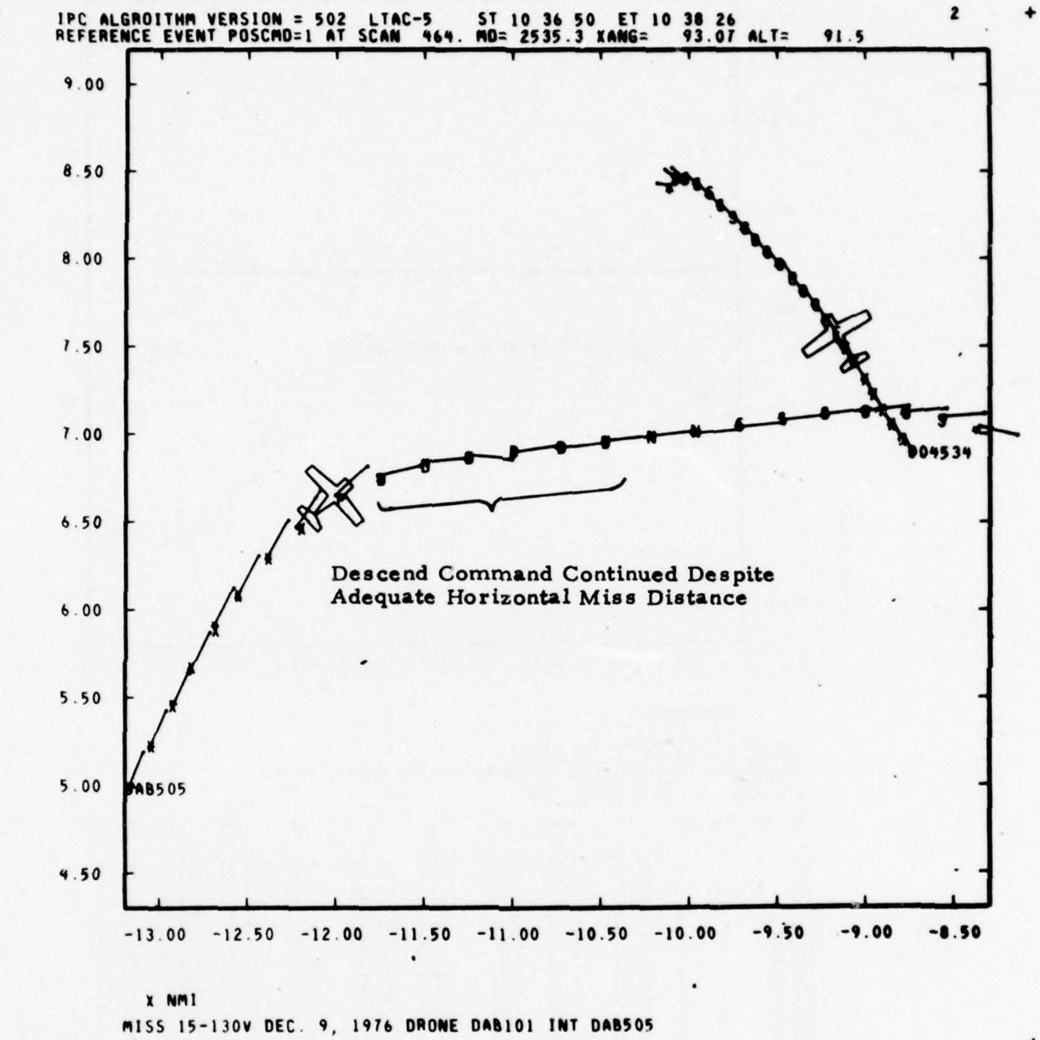
IPC ALGROITHM VERSION = 407 LTAC-4 ST 10 42 58 ET 10 44 44
REFERENCE EVENT POSCMD=1 AT SCAN 130. MD=-1565.0 XANG= 31.38 ALT= 209.5



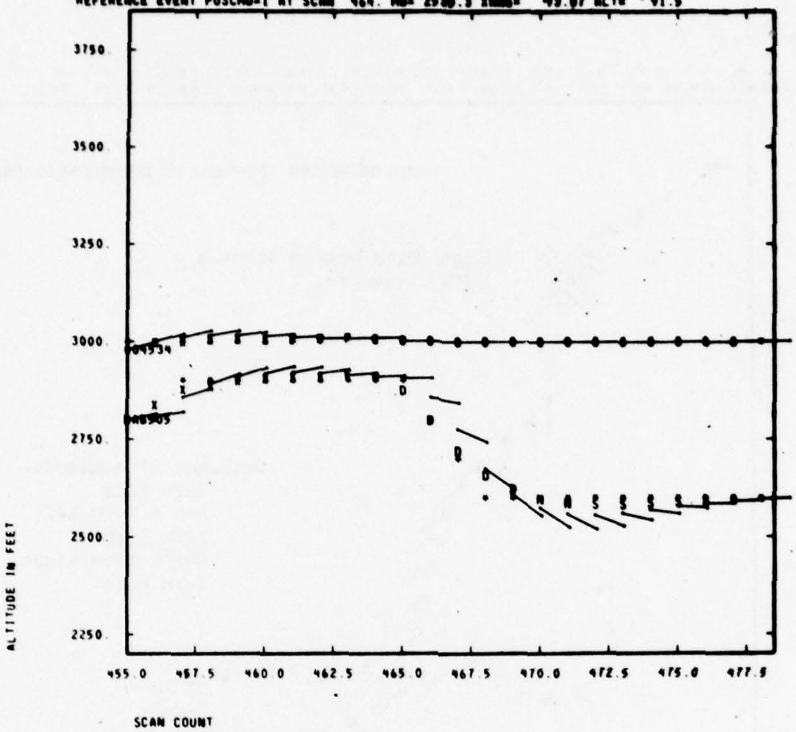
IPC ALGORITHM VERSION = 407 LTAC-4
CPAH = 4645.738 CPAV = 189.484
CPA ON SCAN 134 SCPA = 4677.926 SCPAH = 4645.738 SCPAV = 547.797
AC1 TRACK = 1 ID = DAB505 VFR
AC2 TRACK = 2 ID = DAB552 IFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
115	X	X	0	119.39	3.61	2582.	-58.9	312.68	5.31	312.68	-379.16	68.	0
116	X	X	0	84.22	3.42	5770.	-77.5	318.89	4.11	318.89	-478.88	68.	0
117	X	X	0	74.27	3.24	4125.	-110.9	319.48	2.88	319.48	-482.39	68.	0
118	F	X	0	68.49	3.07	3317.	169.9	270.59	-1.59	162.27	-468.00	68.	0
119	F	X	-2	63.39	2.90	3195.	62.4	234.20	-3.76	0.0	-445.98	68.	2
120	F	X	0	59.36	2.73	3208.	47.9	209.80	-4.38	0.0	-418.68	68.	2
121	NL	S	0	56.43	2.57	3338.	47.9	195.30	-4.08	0.0	-387.31	68.	2
122	NL	S	0	53.78	2.41	3417.	56.5	188.19	-3.33	0.0	-354.90	68.	2
123	NL	S	0	50.79	2.25	3765.	75.9	186.10	-2.45	19.43	-323.27	68.	2
124	NL	S	0	48.44	2.10	3924.	114.9	186.96	-1.63	76.33	-292.13	68.	2
125	NL	S	0	46.24	1.96	3826.	199.3	189.32	-0.95	124.72	-262.57	68.	2
126	NL	S	0	43.06	1.82	3729.	425.8	192.11	-0.45	161.43	-235.61	68.	2
127	NL	S	0	39.91	1.68	3651.	1647.8	194.75	-0.12	186.71	-210.50	68.	2
128	NL	S	0	35.50	1.52	3696.	-2549.7	196.92	0.08	196.92	-187.25	68.	2
129	NL	S	0	32.38	1.40	3352.	-1164.1	198.52	0.17	198.52	-166.32	68.	2
130	NL	S	3	27.36	1.26	3017.	-1018.0	199.59	0.20	199.59	-146.61	68.	2
131	R D	L C	3	22.47	1.13	2474.	-1102.5	200.23	0.18	200.23	-129.32	68.	2
132	R D	L C	3	16.81	1.00	2124.	-69.7	246.94	3.54	246.94	-112.23	68.	2
133	R D	L C	3	12.08	0.90	1683.	-57.8	279.61	4.84	279.61	-96.96	68.	2
134	R D	L C	3	6.58	0.80	960.	-33.8	392.86	11.62	392.86	-83.08	68.	2
135	R D	L C	0	4.21	0.74	2270.	-30.3	515.39	16.99	515.39	-50.52	68.	2
136	RNC	LND	0	-7.10	0.75	4107.	-34.1	593.16	17.42	593.16	32.54	68.	0
137	S	S	0	-8.44	0.85	3075.	-42.0	635.92	15.14	635.92	92.47	68.	0
138	S	S	0	-11.44	1.03	1760.	-113.4	560.71	4.94	560.71	170.50	68.	0
139	S	S	0	-13.59	1.25	560.	97.6	450.98	-4.62	136.72	279.80	68.	0
140	S	S	0	-16.93	1.52	923.	40.8	370.30	-9.08	0.0	382.91	68.	0

EXAMPLE 26
(Encounter 15-130-04)



IPC ALGROITHM VERSION = 502 LTAC-5 ST 10 36 50 ET 10 38 26
REFERENCE EVENT POSCMD=1 AT SCAN 469. MD= 2930.3 XMMD= 93.07 ALT= ·91.5



IPC ALGORITHM VERSION = 502 LTAC-5
CPAH = 7227.562 CPAV = 91.496
CPA ON SCAN 472 SCPA = 7239.543 SCPAH = 7227.562 SCPAV = 416.364
AC1 TRACK = 1 ID = DAB505 IFR
AL2 TRACK =129 ID = 004534 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
455	X	X	0	102.35	5.04	372.	1120.9	160.56	-0.14	151.39	-879.19	64.	0
456	X	X	0	110.65	4.84	8172.	-143.7	178.54	1.24	178.54	-745.51	64.	0
457	X	X	0	98.71	4.61	8189.	-105.9	191.24	1.81	191.24	-757.17	64.	0
458	X	X	0	88.70	4.38	8258.	95.3	152.92	-1.60	50.25	-757.82	64.	0
459	X	X	0	83.62	4.19	7960.	39.0	124.76	-3.20	0.0	-734.46	64.	0
460	X	X	0	76.92	3.96	8002.	29.5	106.10	-3.60	0.0	-710.84	64.	0
461	X	X	0	72.01	3.76	7333.	28.9	95.22	-3.29	0.0	-679.70	64.	0
462	X	F	0	65.28	3.51	6524.	34.0	90.08	-2.65	0.0	-652.47	64.	0
463	X	F	-2	58.39	3.27	5235.	46.0	88.75	-1.93	0.0	-625.80	64.	2
464	F	F	1	45.36	2.98	416.	95.3	93.41	-0.98	30.70	-664.03	64.	2
465	D	C	1	37.60	2.70	6956.	339.2	98.54	-0.29	79.95	-648.66	64.	2
466	D	C	1	33.43	2.39	7968.	222.4	94.75	-0.43	67.49	-558.06	64.	2
467	D	C	1	32.43	2.12	9100.	-44.0	142.53	3.24	142.53	-438.38	64.	2
468	D	C	1	26.46	1.87	7337.	-27.0	223.03	8.25	223.03	-400.54	64.	2
469	D	C	1	24.52	1.62	7367.	-24.5	323.69	13.20	323.69	-307.78	64.	2
470	D	C	1	24.27	1.41	7269.	-27.9	388.52	13.94	388.52	-213.87	64.	2
471	NC	C	1	31.37	1.26	7225.	-34.5	424.92	12.33	424.92	-120.13	64.	2
472	NC	C	0	118.34	1.20	7257.	-45.5	440.91	9.69	440.91	-27.53	64.	0
473	S	S	0	-54.41	1.20	7185.	-64.4	443.59	6.88	443.59	60.98	64.	0
474	S	S	0	-27.47	1.27	7081.	-100.0	438.75	4.39	438.75	195.58	64.	0
475	S	S	0	-23.67	1.41	7025.	-178.4	430.55	2.41	430.55	227.03	64.	0
476	S	S	0	-24.82	1.61	7094.	-417.1	421.77	1.01	421.77	306.01	64.	0
477	S	S	0	-27.17	1.83	7113.	-3695.8	413.92	0.11	413.92	383.70	64.	0
478	S	S	0	-30.32	2.05	7109.	1056.0	407.71	-0.39	383.00	443.64	64.	0

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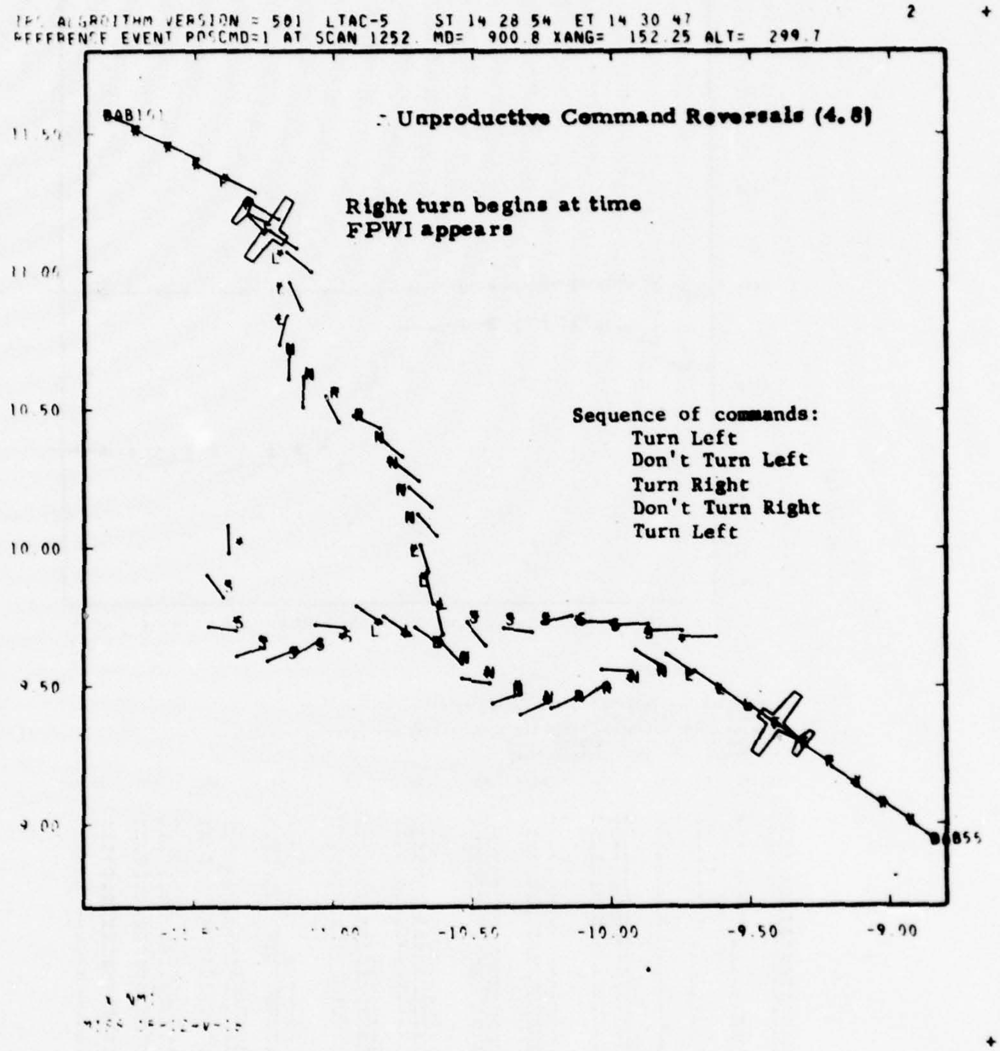
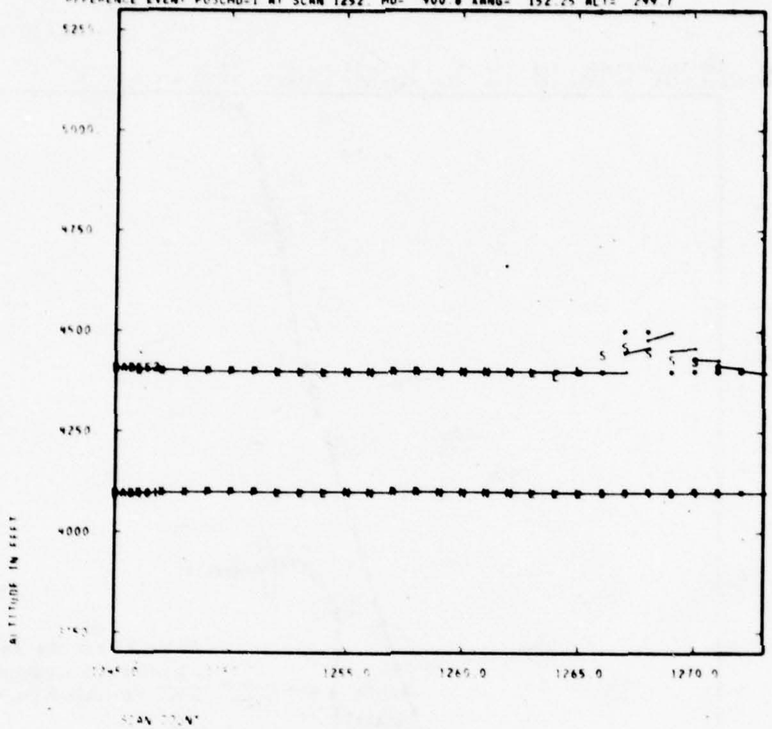
EXAMPLE 27
(Encounter 15-124-16)



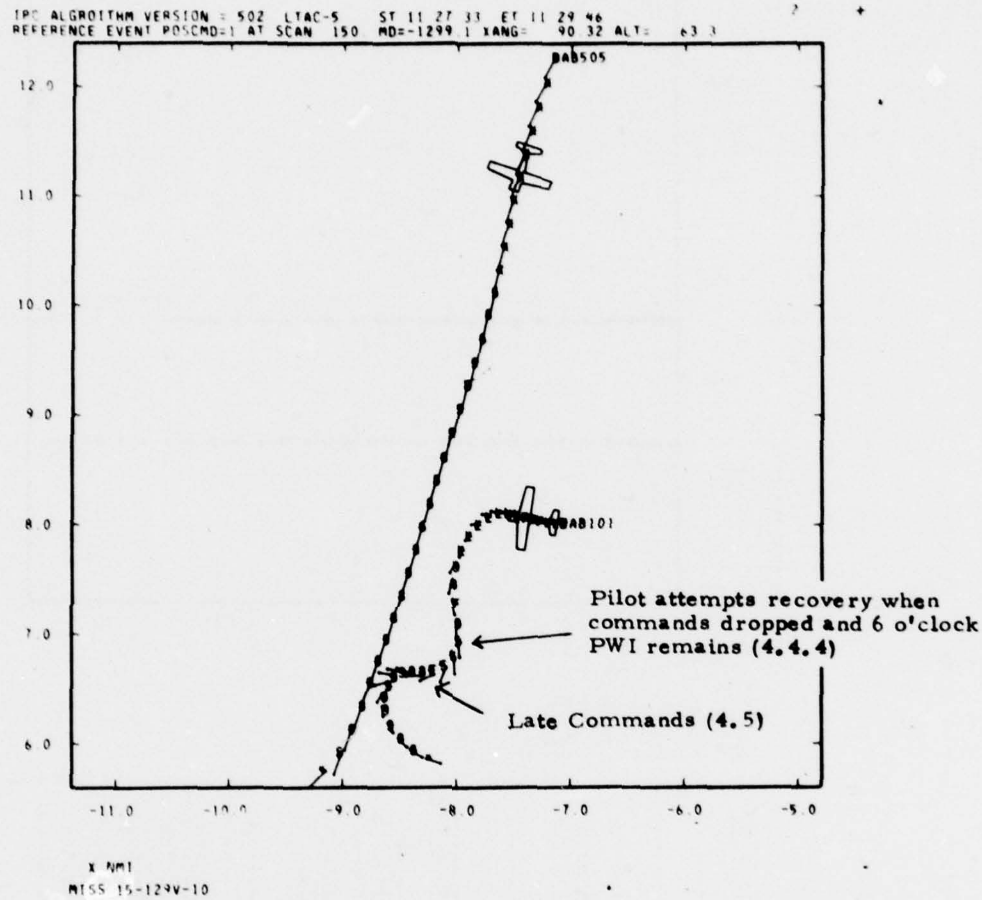
IPC ALGORITHM VERSION = 501 LTAC-5 ST 14 28 54 ET 14 30 47
REFERENCE EVENT POSCMD=1 AT SCAN 1252 MD= 900.8 XANG= 152.25 ALT= 299.7



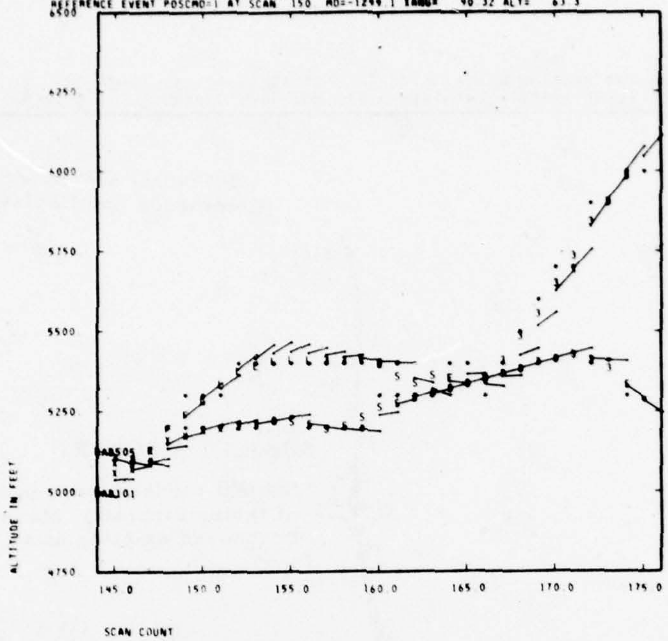
IPC ALGORITHM VERSION = 501 LTAC-5
CPAH = 1172.565 CPAV = 290.719
CPA ON SCAN 1264 SCPA = 1208.067 SCPAH = 1172.565 SCPAV = 290.719
AC1 TRACK = 1 ID = DAB101 IFR
AC2 TRACK = 2 ID = DAB552 IFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
1245	X	X	0	74.81	4.22	5777	-238.4	314.90	1.32	314.90	-843.58	49	0
1246	X	X	0	70.10	3.98	5378	-506.4	310.93	0.61	310.93	-798.47	49	0
1247	X	X	0	65.97	3.75	4908	-2094.1	307.23	0.15	307.23	-751.50	49	0
1248	X	X	0	61.49	3.51	4647	2438.2	304.20	-0.12	298.08	-705.30	49	0
1249	X	X	0	56.88	3.27	4356	1197.2	301.97	-0.25	289.61	-659.63	49	0
1250	F	F	0	52.57	3.03	4101	1057.1	300.50	-0.28	286.57	-612.54	49	0
1251	F	F	-2	47.91	2.79	3361	1150.3	299.63	-0.26	286.87	-566.99	49	2
1252	F	F	1	43.53	2.56	2523	1424.3	299.22	-0.21	288.92	-520.68	49	2
1253	L	L	1	40.01	2.34	1857	1958.2	299.11	-0.15	291.63	-471.75	49	2
1254	L	L	1	38.22	2.14	1508	2992.1	299.19	-0.10	294.29	-407.40	49	2
1255	L	L	0	45.03	1.95	5363	5216.9	299.34	-0.06	296.53	-283.45	49	2
1256	NL	NL	0	36.09	1.77	3814	11424.7	299.52	-0.03	298.23	-286.67	49	2
1257	NL	NL	1	35.85	1.59	965	52015.7	299.68	-0.01	299.40	-230.64	49	2
1258	R	R	1	42.92	1.44	4568	-49953.0	299.82	0.01	299.82	-154.87	49	2
1259	R	R	0	35.59	1.30	6041	-25966.9	299.91	0.01	299.91	-146.33	49	2
1260	NR	NR	0	30.40	1.14	5254	-23241.8	299.98	0.01	299.98	-124.17	49	2
1261	NR	NR	0	23.79	0.95	4496	-25664.6	300.02	0.01	300.02	-101.59	49	2
1262	NR	NR	0	12.50	0.77	3128	-31971.6	300.04	0.01	300.04	-103.26	49	2
1263	NR	NR	1	3.37	0.57	1514	-44023.6	300.04	0.01	300.04	-95.16	49	2
1264	L	L	1	-6.48	0.36	965	-66433.6	300.04	0.0	300.04	-57.38	49	2
1265	L	L	1	-29.64	0.21	1028	100.0	300.03	0.0	300.03	-23.38	49	2
1266	L	L	0	55.19	0.21	1224	100.0	300.02	0.0	300.02	12.77	49	0
1267	S	S	0	2.68	0.43	1363	100.0	300.02	0.0	300.02	64.47	49	0
1268	S	S	0	-6.41	0.66	603	-99.8	346.41	3.47	346.41	116.15	49	0
1269	S	S	0	-11.92	0.90	1010	-78.5	379.02	4.83	379.02	170.56	49	0
1270	S	S	0	-16.75	1.13	567	-254.3	353.09	1.39	353.09	219.28	49	0
1271	S	S	0	-21.35	1.35	559	510.9	331.55	-0.65	299.75	266.41	49	0
1272	S	S	0	-29.82	1.53	3083	191.5	315.46	-1.65	234.73	254.17	49	0

EXAMPLE 28
(Encounter 15-129-10)



IPC ALGROITHM VERSION = 502 LTAC-5 ST 11 27 33 ET 11 29 46
REFERENCE EVENT POSCMD=1 AT SCAN 150 MD=-1299.1 XANG= 90.32 ALT= 63.3

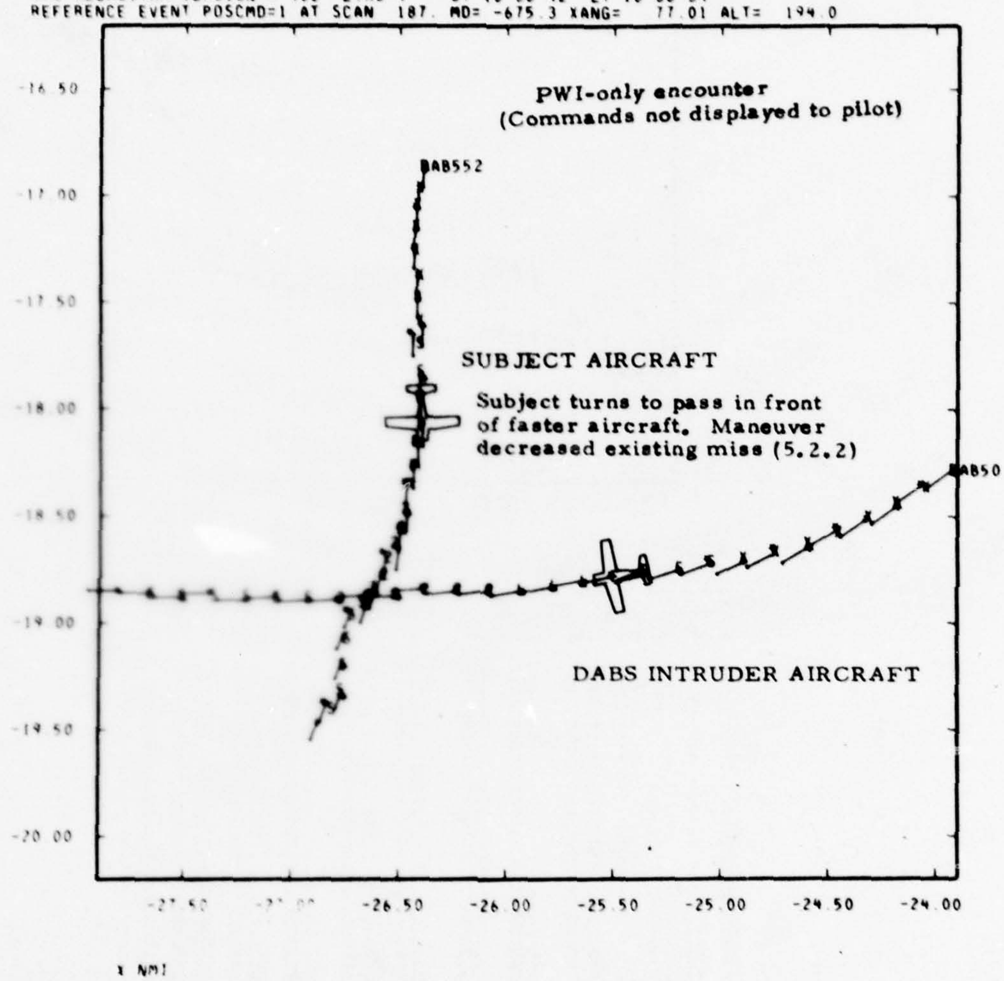


IPC ALGORITHM VERSION = 502 LTAC-5
CPAH = 1748.235 CPAV = 0.004
CPA ON SCAN 171 SCPA = 1774.979 SCPAH = 1748.235 SCPAV = 306.961
AC1 TRACK = 1 ID = DAB505 IFR
AC2 TRACK = 2 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
144	X	X	0	91.70	4.46	5256	-353.8	-132.78	-0.38	132.78	-767.46	68	0
145	X	X	0	86.63	4.26	5121	-1548.9	-130.27	-0.08	130.27	-737.66	68	0
146	X	X	0	80.92	4.04	4450	13.1	-66.67	5.07	0.0	-708.13	68	0
147	X	X	0	74.50	3.81	3570	4.1	-25.91	6.25	0.0	-682.34	68	0
148	X	F	0	68.53	3.58	2454	0.1	-0.93	6.03	0.0	-654.46	68	0
149	X	F	-2	62.91	3.36	1504	-2.5	12.94	5.19	12.94	-624.03	68	2
150	X	F	1	57.26	3.13	802	-8.7	64.97	7.43	64.97	-591.46	68	2
151	X	L	1	51.21	2.89	274	-12.9	97.90	7.57	97.90	-558.21	68	2
152	X	L	1	46.11	2.66	473	-17.7	115.91	6.55	115.91	-519.85	68	2
153	X	L	1	41.40	2.43	1199	-20.0	169.70	8.49	169.70	-477.81	68	2
154	X	L	1	38.67	2.24	1871	-24.4	202.86	8.31	202.86	-429.82	68	2
155	S	L	1	43.80	2.10	2487	-33.7	209.45	6.22	209.45	-330.52	68	2
156	S	L	1	54.21	1.99	891	-52.5	203.99	3.89	203.99	-238.03	68	2
157	S	L	3	59.79	1.91	556	-38.0	221.04	5.81	221.04	-195.63	68	2
158	S	L	3	59.71	1.84	1576	-51.0	225.75	4.43	225.75	-178.71	68	2
159	S	L	0	70.62	1.79	978	-78.0	223.77	2.87	223.77	-141.86	68	0
160	S	F	0	79.23	1.75	7504	-131.6	219.42	1.67	219.42	-119.49	68	0
161	S	S	0	101.63	1.72	7302	72.2	168.11	-2.33	9.87	-88.08	68	0
162	S	S	0	122.57	1.68	8391	31.1	131.00	-4.22	0.0	-68.53	68	0
163	S	S	0	124.48	1.61	8204	7.6	60.30	-7.91	0.0	-60.99	68	0
164	S	S	0	74.08	1.50	1163	1.6	13.89	-8.76	0.0	-86.71	68	0
165	S	F	3	28.85	1.35	2864	4.4	23.33	-5.35	0.0	-170.07	68	2
166	R D	L C	3	15.75	1.16	2065	8.6	28.48	-3.33	0.0	-205.26	68	2
167	R D	L C	3	7.36	0.92	1079	-3.2	-17.87	-5.63	17.87	-205.58	68	2
168	R D	L C	3	1.27	0.69	1044	-2.7	-8.73	-3.21	8.73	-137.83	68	2
169	R D	L C	3	-5.48	0.52	765	-27.3	41.04	1.50	41.04	-100.55	68	2
170	R D	L C	3	-14.86	0.39	479	-17.4	117.39	6.75	117.39	-59.89	68	2
171	R D	L C	3	-35.96	0.30	484	-18.2	209.20	11.52	209.20	-30.20	68	2
172	R D	L C	3	-90.96	0.25	1310	-22.1	262.18	11.84	262.18	-13.09	68	2
172			3	-90.96	0.25	1310	-22.1	262.18	11.84	262.18	-13.09	68	2
173	R D	L C	3	-118.54	0.27	1592	-19.9	412.67	20.73	412.67	-10.00	68	2
174	R D	L C	0	20.28	0.41	1857	-24.9	500.19	20.09	500.19	43.45	68	0
174			0	20.28	0.41	1857	-24.9	500.19	20.09	500.19	43.45	68	0
175	S	S	0	1.69	0.62	2058	-22.8	669.01	29.37	669.01	96.61	68	0

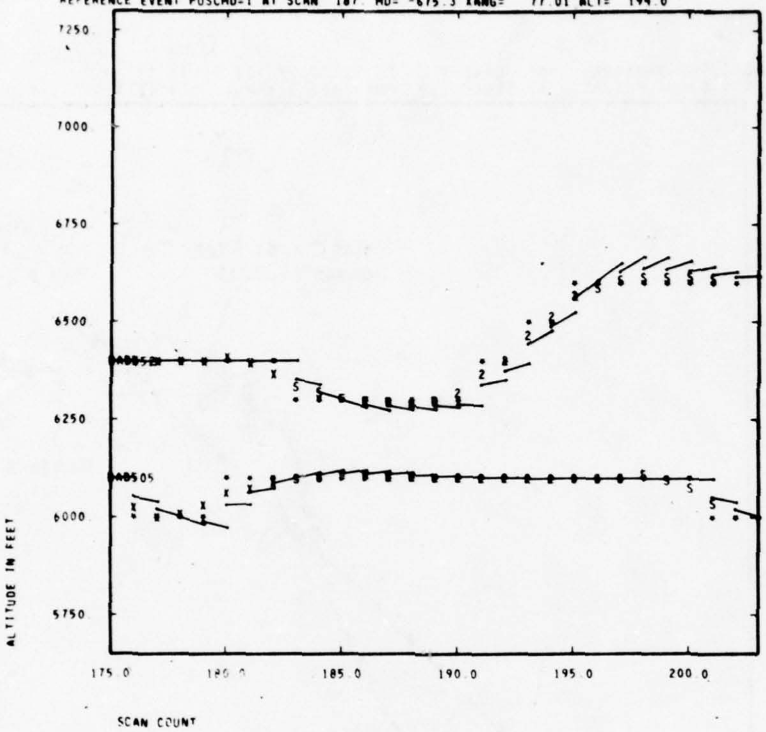
EXAMPLE 29
(Encounter 14-111-04)

IPC ALGROITHM VERSION = 408 LTAC-4 ST 10 36 42 ET 10 38 34
REFERENCE EVENT POSCMD=1 AT SCAN 187. MD= -675.3 XANG= 77.01 ALT= 194.0



MISS 14-111S-04

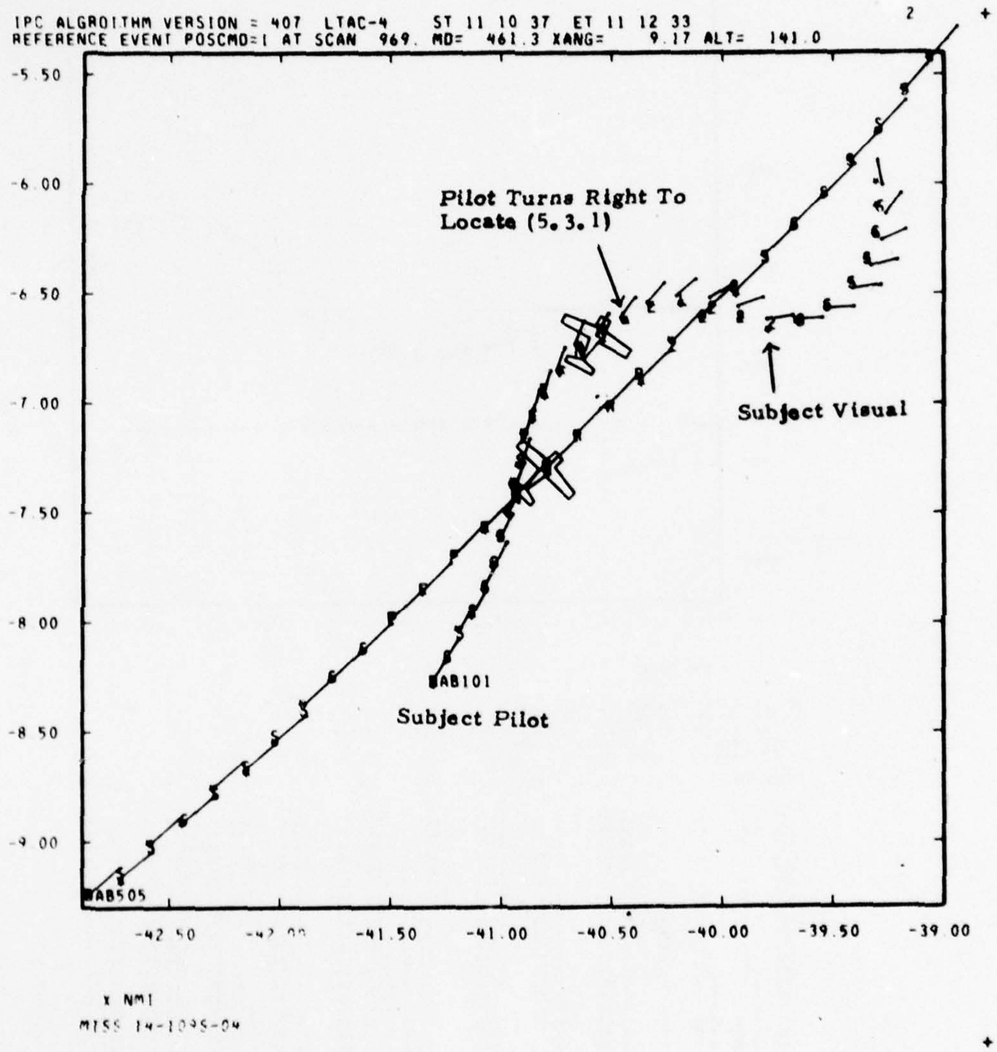
IPC ALGROITHM VERSION = 408 LTAC-4 ST 10 36 42 ET 10 38 39
REFERENCE EVENT POSCMD=1 AT SCAN 187 MD= -675.3 XANG= 77.01 ALT= 194.0



IPC ALGORITHM VERSION = 408 LTAC-4
CPAH = 734.249 CPAV = 181.559
CPA ON SCAN 194 SCPA = 843.245 SCPAH = 734.249 SCPAV = 414.656
AC1 TRACK = 2 ID = DAB505 VFR
AC2 TRACK = 1 ID = DAB552 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
175	X	X	0	106.22	2.98	6419.	-66424.7	-299.83	0.0	299.83	-291.55	32.	0
176	X	X	0	99.96	2.85	6074.	-31035.2	-299.92	-0.01	299.92	-281.35	32.	0
177	X	X	0	94.70	2.73	6045.	-99.8	-346.38	-3.47	346.38	-270.79	32.	0
178	X	X	0	95.39	2.64	6460.	-78.3	-378.95	-4.84	378.95	-251.79	32.	0
179	X	X	0	89.45	2.51	6296.	-81.9	-399.44	-4.88	399.44	-241.79	32.	0
180	X	X	0	81.18	2.37	5689.	-97.8	-410.50	-4.20	410.50	-236.32	32.	0
181	X	X	0	74.00	2.24	5373.	1464.3	-368.54	0.25	360.48	-229.26	32.	0
182	X	X	0	61.78	2.05	4346.	129.6	-336.18	2.59	253.17	-229.10	32.	0
183	X	X	0	51.43	1.88	3568.	90.1	-313.64	3.48	202.24	-226.08	32.	0
184	S	S	0	46.43	1.75	3200.	36.5	-253.19	6.93	31.34	-214.26	32.	0
185	S	S	0	35.52	1.52	2186.	27.4	-213.18	7.79	0.0	-205.54	32.	0
186	F	F	-2	28.51	1.35	1649.	26.6	-189.73	7.13	0.0	-190.69	32.	2
187	F	F	1	21.28	1.15	1138.	31.1	-178.66	5.75	0.0	-171.40	32.	2
188	L	R	1	17.41	1.01	1015.	42.1	-175.84	4.17	42.26	-149.59	32.	2
189	L	R	1	12.90	0.86	880.	65.1	-177.79	2.73	90.33	-125.63	32.	2
190	L	R	2	8.96	0.74	872.	116.3	-182.04	1.57	131.96	-102.73	32.	2
191	L D	R C	2	-0.18	0.54	593.	262.4	-186.92	0.71	164.12	-76.30	32.	2
192	L D	R C	2	-8.84	0.39	547.	-71.4	-237.81	-3.33	237.81	-54.49	32.	2
193	L D	R C	2	-27.93	0.23	523.	-54.6	-274.05	-5.02	274.05	-30.16	32.	2
194	L D	R C	2	-44.85	0.19	731.	-39.6	-343.66	-8.67	343.66	-18.93	32.	2
195	L D	R C	3	-90.76	0.12	704.	-41.4	-388.99	-9.38	388.99	0.60	32.	2
196	L D	L C	0	53.68	0.17	722.	-38.8	-461.27	-11.90	461.27	15.34	32.	0
197	S	S	0	22.55	0.27	715.	-43.8	-505.66	-11.54	505.66	28.70	32.	0
198	S	S	0	12.58	0.35	732.	-54.6	-528.64	-9.68	528.64	35.98	32.	0
199	S	S	0	1.16	0.48	682.	-73.7	-536.72	-7.28	536.72	50.59	32.	0
200	S	S	0	-9.45	0.68	622.	-108.2	-535.77	-4.95	535.77	78.98	32.	0
201	S	S	0	-15.89	0.86	676.	-177.2	-530.14	-2.99	530.14	106.21	32.	0
202	S	S	0	-20.22	0.97	754.	-114.3	-569.22	-4.98	569.22	119.79	32.	0

EXAMPLE 30
(Encounter 14-109-04)



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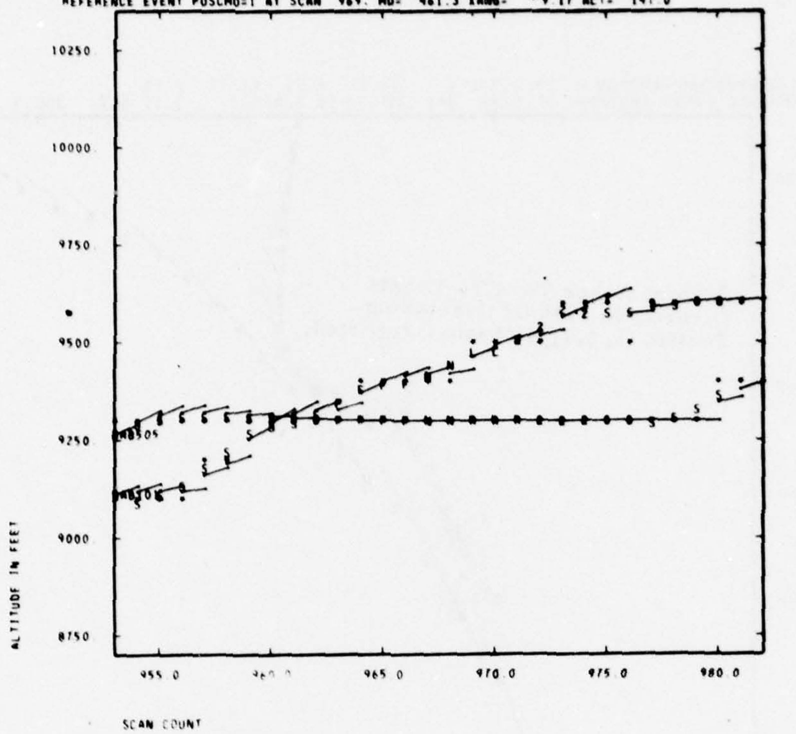
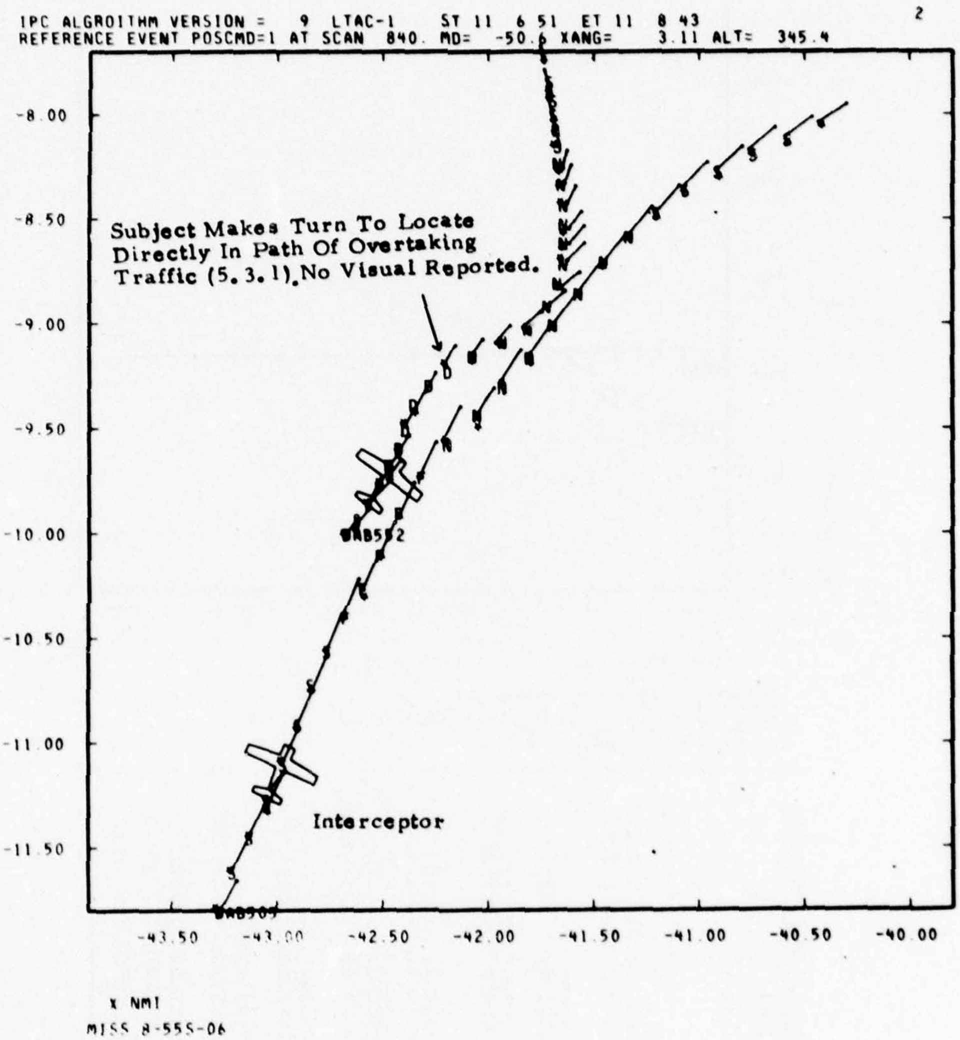
IPC ALGROITHM VERSION = 407 LTAC-4 ST 11 10 37 ET 11 12 33
REFERENCE EVENT POSCMD=1 AT SCAN 969. MD= 461.3 XANG= '9.17 ALT= 741.0



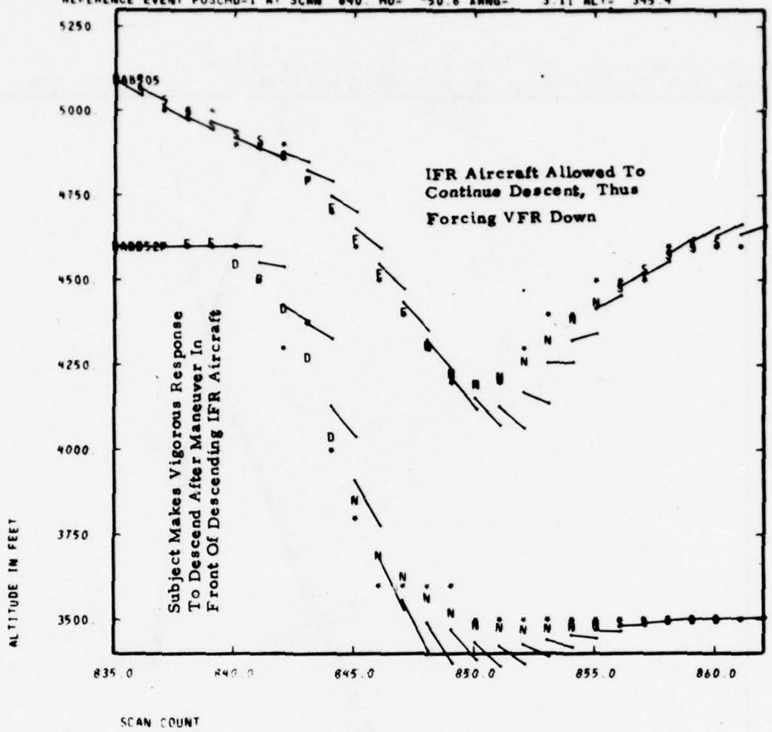
IPC ALGORITHM VERSION = 407 LTAC-4
CPAH = 1023.141 CPAV = 10.863
CPA ON SCAN 973 SCPA = 1061.675 SCPAH = 1023.141 SCPAV = 283.437
AC1 TRACK = 3 ID = DAB505 VFR
AC2 TRACK = 2 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
953	S	S	0	88.15	1.94	3308	57.3	123.52	-2.16	54.49	-138.60	32	0
954	S	S	0	79.35	1.84	2509	-191.5	154.28	0.81	154.28	-136.30	32	0
955	S	S	0	78.61	1.77	3549	-77.6	177.25	2.28	177.25	-127.19	32	0
956	S	S	0	75.73	1.70	3769	-70.2	192.90	2.75	192.90	-119.18	32	0
957	S	S	0	72.20	1.62	3882	-77.9	202.25	2.60	202.25	-112.01	32	0
958	S	S	0	66.37	1.53	3661	120.4	160.57	-1.33	117.91	-106.55	32	0
959	S	S	0	64.84	1.46	4416	39.9	129.49	-3.25	25.50	-97.73	32	0
960	S	S	0	62.20	1.38	4856	8.5	62.22	-7.29	0.0	-89.41	32	0
961	S	S	0	53.50	1.28	4394	2.0	17.13	-8.40	0.0	-85.63	32	0
962	S	S	0	49.30	1.21	4468	-1.2	-9.47	-7.79	9.47	-78.86	32	0
963	S	S	0	43.40	1.12	4430	-3.5	-22.32	-6.34	22.32	-72.33	32	0
964	F	F	0	38.63	1.03	4494	-5.6	-26.03	-4.65	26.03	-64.38	32	0
965	F	F	0	32.21	0.95	4223	-10.8	-70.66	-6.55	70.66	-58.19	32	0
966	F	F	-2	22.90	0.85	3736	-14.9	-98.85	-6.63	98.85	-53.18	32	2
967	F	F	0	19.77	0.79	3665	-20.0	-114.12	-5.71	114.12	-45.88	32	2
968	NL	NR	0	13.95	0.74	3412	-27.3	-120.24	-4.40	120.24	-39.91	32	2
969	NL	NR	1	5.57	0.66	2881	-39.4	-120.61	-3.06	120.61	-36.02	32	2
970	R	L	1	-6.24	0.57	2114	-30.5	-164.24	-5.38	164.24	-33.40	32	2
971	R	L	1	-16.36	0.50	1492	-32.9	-192.77	-5.85	192.77	-30.18	32	2
972	R	L	2	-29.41	0.41	706	-39.8	-209.14	-5.26	209.14	-26.69	32	2
973	R D	L C	2	-59.92	0.27	412	-51.8	-216.57	-4.18	216.57	-19.59	32	2
974	R D	L C	2	-133.00	0.16	885	-40.8	-264.57	-6.48	264.57	-10.00	32	2
975	R D	L C	0	116.27	0.20	1003	-43.6	-295.39	-6.78	295.39	11.01	32	0
976	S	S	0	34.82	0.32	1061	-52.4	-312.55	-5.96	312.55	30.85	32	0
977	S	S	0	20.33	0.41	1061	-229.9	-273.56	-1.19	273.56	42.32	32	0
978	S	S	0	16.10	0.45	962	-148.8	-288.47	-1.94	288.47	45.17	32	0
979	S	S	0	12.76	0.49	859	-144.6	-298.11	-2.06	298.11	45.23	32	0
980	S	S	0	12.19	0.50	777	-165.9	-303.57	-1.83	303.57	40.23	32	0
981	S	S	0	8.31	0.56	2295	127.5	-259.56	2.04	194.41	29.90	32	0

EXAMPLE 31
(Encounter 8-55-06)



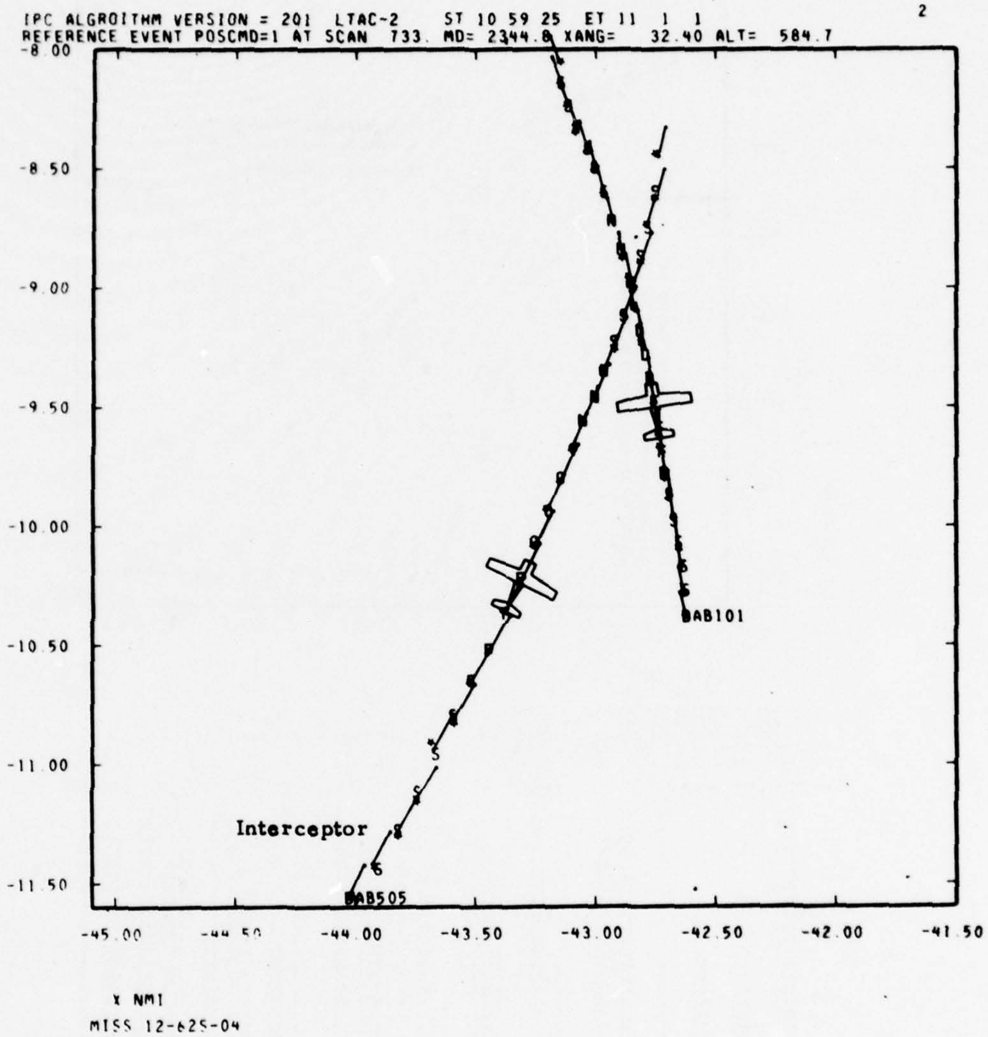
IPC ALGROITHM VERSION = 9 LTAC-1 ST 11 6 51 ET 11 8 43
REFERENCE EVENT POSCMD=1 AT SCAN 840. MD= -50.6 XANG= 3.11 ALT= 345.4



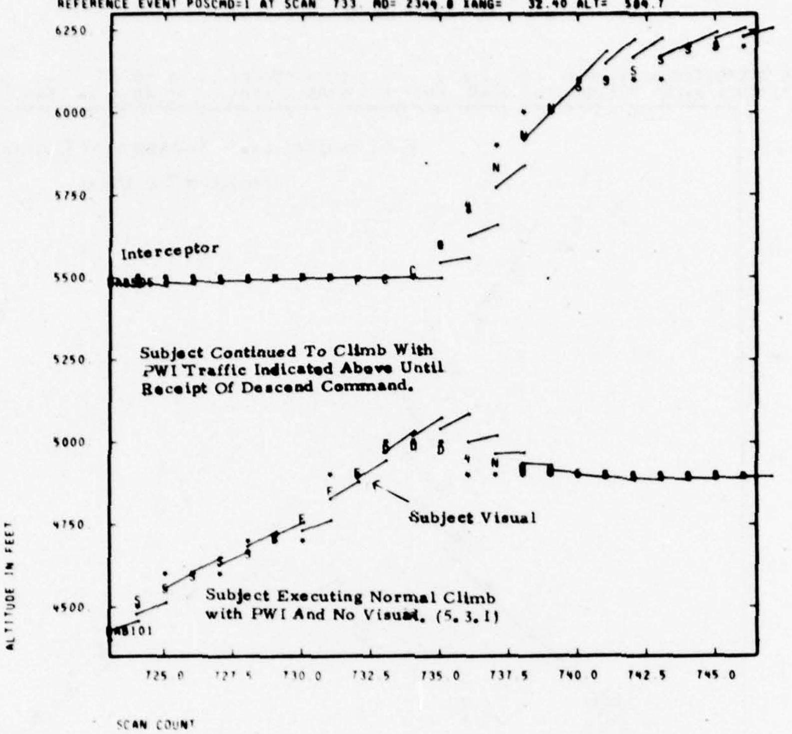
IPC ALGORITHM VERSION = 9 LTAC-1
CPAH = 2570.898 CPAV = 345.414
CPA ON SCAN 853 SCPA = 2707.789 SCPAH = 2570.898 SCPAV = 850.062
AC1 TRACK = 2 ID = DAB505 IFR
AC2 TRACK = 3 ID = DAB552 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
835			0	102.51	2.01	231.	46.2	-538.66	11.67	0.0	-130.43	64.	0
836	S	S	0	84.44	1.90	76.	44.0	-491.52	11.18	0.0	-138.69	64.	0
837	S	S	0	66.62	1.75	821.	50.4	-468.84	9.30	0.0	-146.59	64.	0
838	S	F	-2	61.64	1.67	733.	40.9	-414.23	10.14	0.0	-142.29	64.	2
839	S	F	0	64.44	1.63	322.	42.0	-383.56	9.14	0.0	-129.50	64.	2
840	S	F	1	51.44	1.47	908.	50.9	-370.27	7.27	0.0	-126.75	64.	2
841	S	D	1	48.88	1.40	709.	36.9	-321.93	8.73	0.0	-118.52	64.	2
842	S	D	1	47.67	1.34	222.	71.8	-339.02	4.72	36.87	-107.86	64.	2
843	S	D	1	40.38	1.22	381.	-88.5	-449.65	-5.08	449.65	-100.55	64.	2
844	F	D	1	35.99	1.13	360.	-129.9	-449.49	-3.46	449.49	-92.55	64.	2
845	F	D	0	43.48	1.15	1.	-55.1	-617.78	-11.22	617.78	-81.66	64.	2
846	F	NC	0	36.89	1.04	1284.	-39.5	-741.29	-18.76	741.29	-71.43	64.	2
847	F	NC	0	32.11	0.95	2457.	-39.9	-857.49	-21.46	857.49	-62.54	64.	2
848	F	NC	0	25.50	0.86	3230.	-53.6	-879.71	-16.42	879.71	-53.42	64.	2
849	ND	NC	0	19.57	0.80	3223.	-104.4	-833.82	-7.99	833.82	-46.70	64.	2
850	ND	NC	0	15.75	0.75	2380.	761.3	-743.78	0.98	681.25	-43.66	64.	2
851	ND	NC	0	5.36	0.66	1029.	310.1	-721.12	2.33	572.31	-40.34	64.	2
852	ND	NC	0	-3.66	0.57	615.	261.1	-706.15	2.70	533.08	-35.83	64.	2
853	ND	NC	0	-17.44	0.46	1395.	-938.7	-743.39	-0.79	743.39	-28.73	64.	2
854	ND	NC	0	-34.52	0.42	2172.	-141.5	-817.93	-5.78	817.93	-17.77	64.	2
855	ND	NC	0	-157.90	0.42	2546.	-115.0	-869.90	-7.57	869.90	-3.66	64.	2
856	ND	NC	0	0.0	0.45	2589.	0.0	-948.08	0.0	948.08	12.47	64.	0
857	S	S	0	0.0	0.57	2755.	0.0	-997.98	0.0	997.98	40.18	64.	0
858	S	S	0	0.0	0.67	2690.	0.0	-1024.38	0.0	1024.38	62.13	64.	0
859	S	S	0	0.0	0.82	2655.	0.0	-1081.26	0.0	1081.26	87.32	64.	0
860	S	S	0	0.0	0.98	2606.	0.0	-1114.79	0.0	1114.79	115.13	64.	0
861	S	S	0	0.0	1.15	2484.	0.0	-1129.76	0.0	1129.76	145.60	64.	0

EXAMPLE 32
(Encounter 10-062-04)



IPC ALGROITHM VERSION = 201 LTAC-2 ST 10 59 25 ET 11 1 1
REFERENCE EVENT POSCMD=1 AT SCAN 733 MD= 2344.8 XANG= 32.40 ALT= 584.7



IPC ALGORITHM VERSION = 201 LTAC-2
CPAH = 3424.136 CPAV = 516.441
CPA ON SCAN 746 SCPA = 3663.083 SCFAH = 3424.136 SCPAV = 1301.332
AC1 TRACK = 2 ID = DAB505 VFR
AC2 TRACK = 1 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
723			0	81.16	1.92	2687	80.5	1078.99	-13.41	649.98	-151.46	32	0
724	S	S	0	74.71	1.82	3455	98.5	1058.86	-10.75	714.94	-145.92	32	0
725	S	S	0	69.45	1.73	3961	89.6	1007.62	-11.24	647.83	-138.91	32	0
726	S	S	0	65.26	1.64	4497	69.9	932.62	-13.35	505.42	-130.22	32	0
727	S	S	0	58.26	1.53	4147	70.7	887.72	-12.56	485.94	-124.44	32	0
728	S	S	0	48.11	1.40	3041	83.9	865.48	-10.32	535.18	-121.38	32	0
729	S	S	0	43.63	1.30	3085	73.1	812.09	-11.10	456.80	-112.90	32	0
730	F	F	0	36.73	1.19	2548	78.8	781.78	-9.92	464.24	-105.89	32	0
731	F	F	0	34.28	1.11	2812	97.7	768.11	-7.86	516.48	-94.86	32	0
732	F	F	-2	27.62	0.99	2136	53.5	672.61	-12.56	270.55	-86.93	32	2
733	F	F	1	25.47	0.92	2331	46.0	610.90	-13.27	186.30	-76.08	32	2
734	C	D	1	21.25	0.84	2149	34.9	529.86	-15.20	43.55	-66.54	32	2
735	C	D	1	19.86	0.78	2532	34.3	482.20	-14.04	32.77	-55.54	32	2
736	C	D	4	13.52	0.69	2201	63.7	505.54	-7.94	251.58	-47.82	32	2
737	C	D	0	10.73	0.64	2345	-182.4	624.52	3.42	624.52	-39.51	32	2
738	ND	NC	0	11.60	0.62	2776	-50.6	806.37	15.93	806.37	-30.32	32	2
739	ND	NC	0	13.09	0.59	3052	-41.1	978.05	23.82	978.05	-21.81	32	2
740	ND	NC	0	28.63	0.61	3514	-44.2	1087.74	24.62	1087.74	-11.85	32	0
741	S	S	0	51.17	0.64	3884	-47.9	1194.60	24.97	1194.60	-10.00	32	0
742	S	S	0	46.65	0.63	3783	-58.1	1252.77	21.56	1252.77	-10.00	32	0
743	S	S	0	38.94	0.61	3605	-76.8	1276.36	16.63	1276.36	-10.00	32	0
744	S	S	0	0.0	0.61	3546	0.0	1277.99	0.0	1277.99	12.44	32	0
745	S	S	0	0.0	0.61	3460	0.0	1314.04	0.0	1314.04	14.48	32	0
746	S	S	0	0.0	0.63	3478	0.0	1331.34	0.0	1331.34	17.12	32	0

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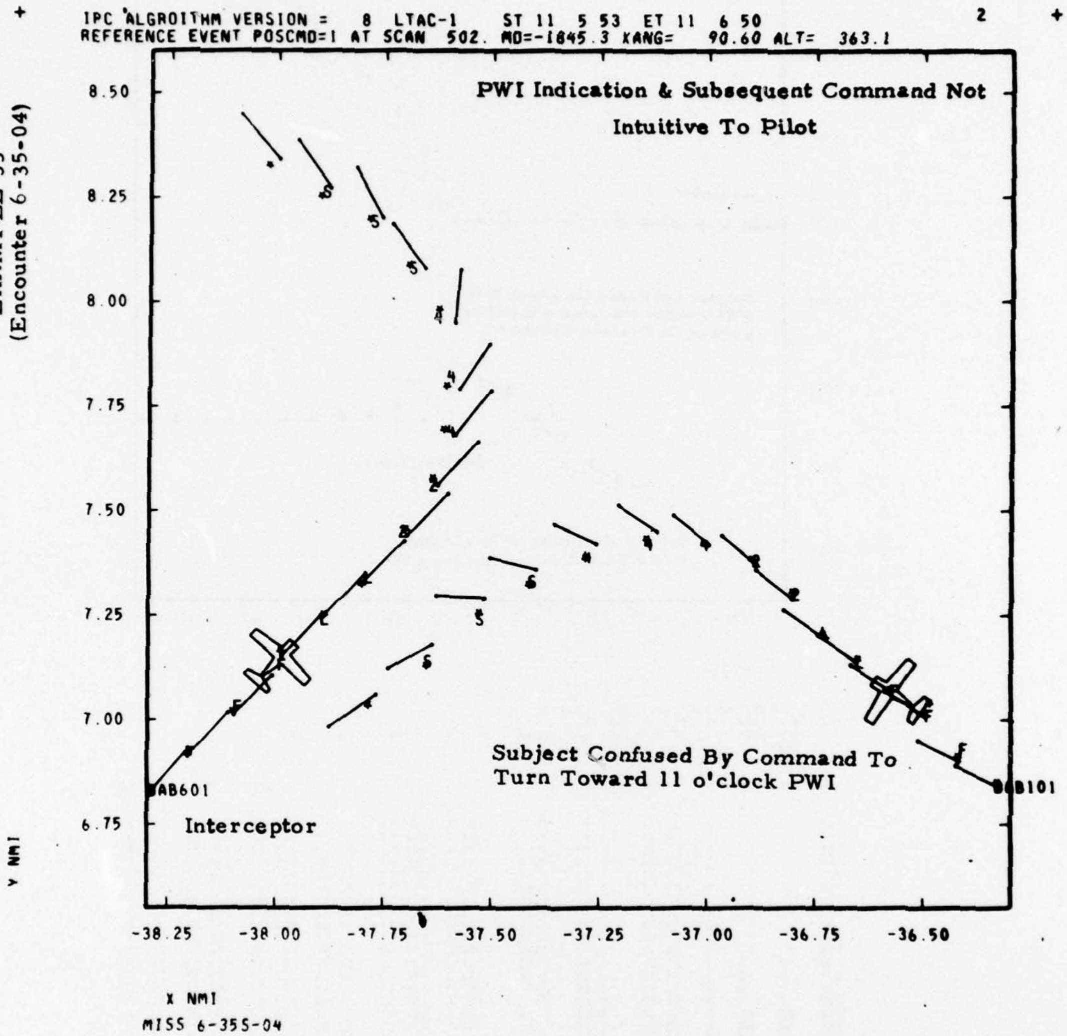
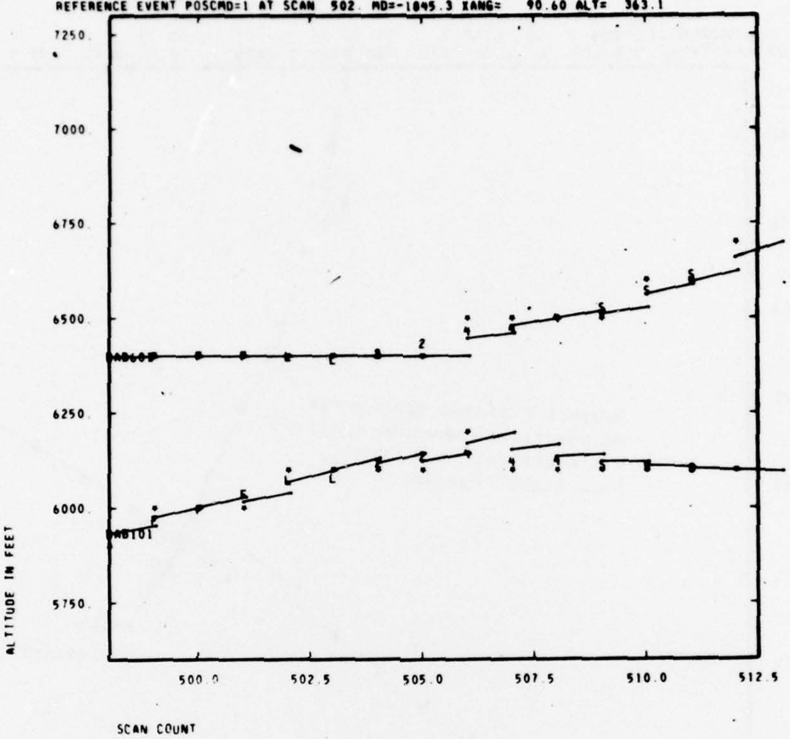
EXAMPLE 33
(Encounter 6-35-04)



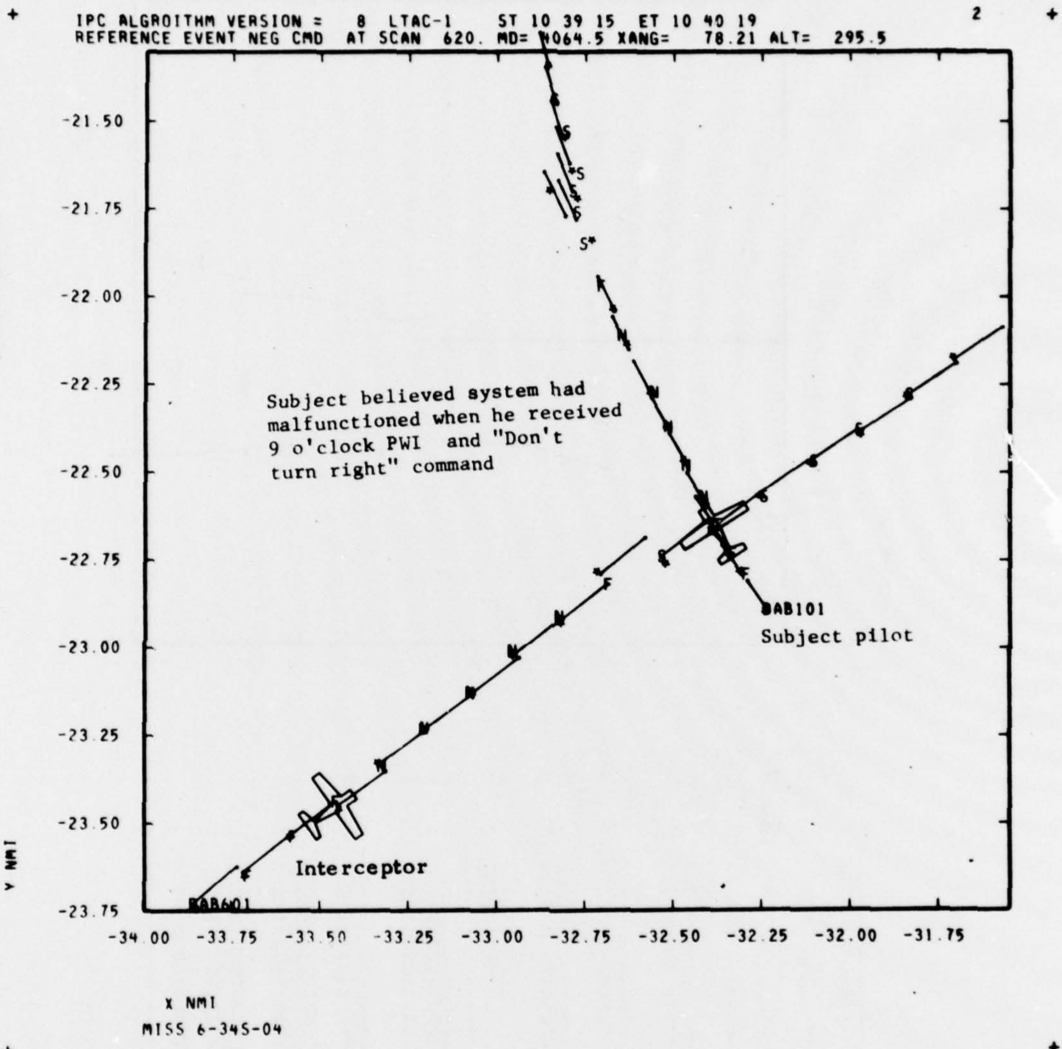
IPC ALGROITHM VERSION = 8 LTAC-1 ST 11 5 53 ET 11 6 50
REFERENCE EVENT POSCMD=1 AT SCAN 502. MD=-1845.3 XANG= 90.60 ALT= 363.1



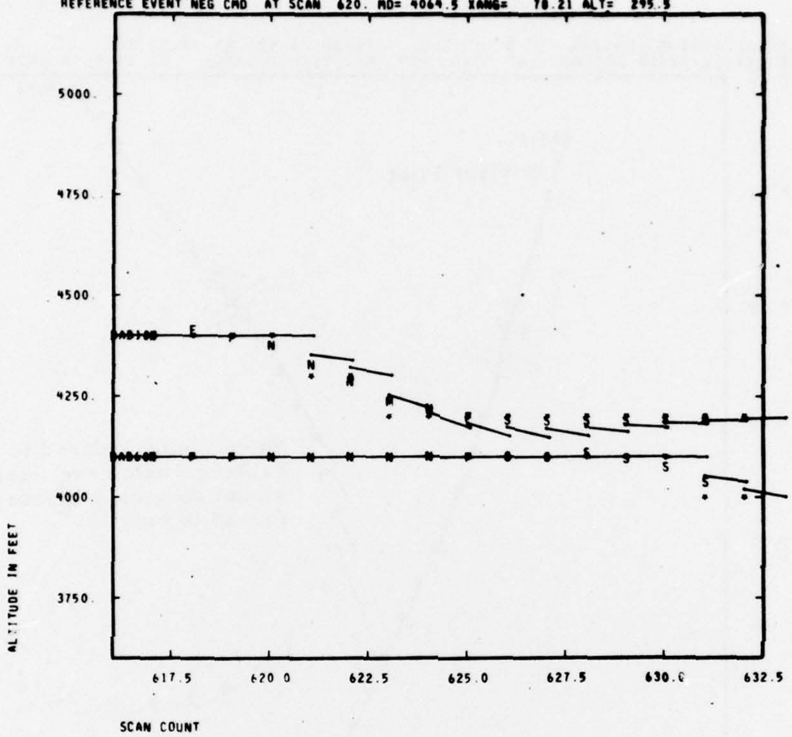
IPC ALGORITHM VERSION = 8 LTAC-1
CPAH = 3677.070 CPAV = 287.914
CPA ON SCAN 507 SCPA = 3693.563 SCPAH = 3677.070 SCPAV = 348.668
AC1 TRACK = 1 ID = DAB601 VFR
AC2 TRACK = 2 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	ICMD	NAC
498			0	44.49	2.15	3477.	62.9	-467.74	7.43	229.98	-350.83	32.	0
499	F	F	0	39.78	1.96	3027.	89.6	-466.66	5.21	300.02	-323.52	32.	0
500	F	F	0	35.53	1.78	2663.	62.2	-424.43	6.83	205.94	-293.49	32.	0
501	F	F	-2	31.55	1.61	1885.	59.4	-398.12	6.70	183.59	-263.22	32.	2
502	F	F	1	27.06	1.42	2177.	67.7	-384.12	5.67	202.55	-229.60	32.	?
503	L	L	1	22.73	1.24	2102.	42.6	-332.59	7.80	82.86	-197.92	32.	?
504	L	L	2	18.67	1.07	1931.	38.4	-300.32	7.82	49.92	-167.49	32.	?
505	L C	L D	2	14.09	0.91	1838.	42.2	-283.06	6.71	68.35	-137.57	32.	?
506	L C	L D	4	9.59	0.76	1916.	53.7	-276.28	5.14	111.68	-108.64	32.	?
507	L C	L D	4	6.23	0.65	2278.	77.4	-276.04	3.57	161.92	-80.55	32.	?
508	L C	L D	4	3.68	0.57	2734.	-247.2	-325.78	-1.32	325.78	-51.72	32.	?
509	L C	L D	0	0.0	0.62	3787.	0.0	-363.09	0.0	363.09	5.29	32.	0
510	S	S	0	0.0	0.76	3068.	0.0	-388.45	0.0	388.45	42.24	32.	0
511	S	S	0	0.0	0.93	3541.	0.0	-450.03	0.0	450.03	82.01	32.	0
512	S	S	0	0.0	1.11	2402.	0.0	-490.20	0.0	490.20	163.75	32.	0

EXAMPLE 34
(Encounter 6-34-04)



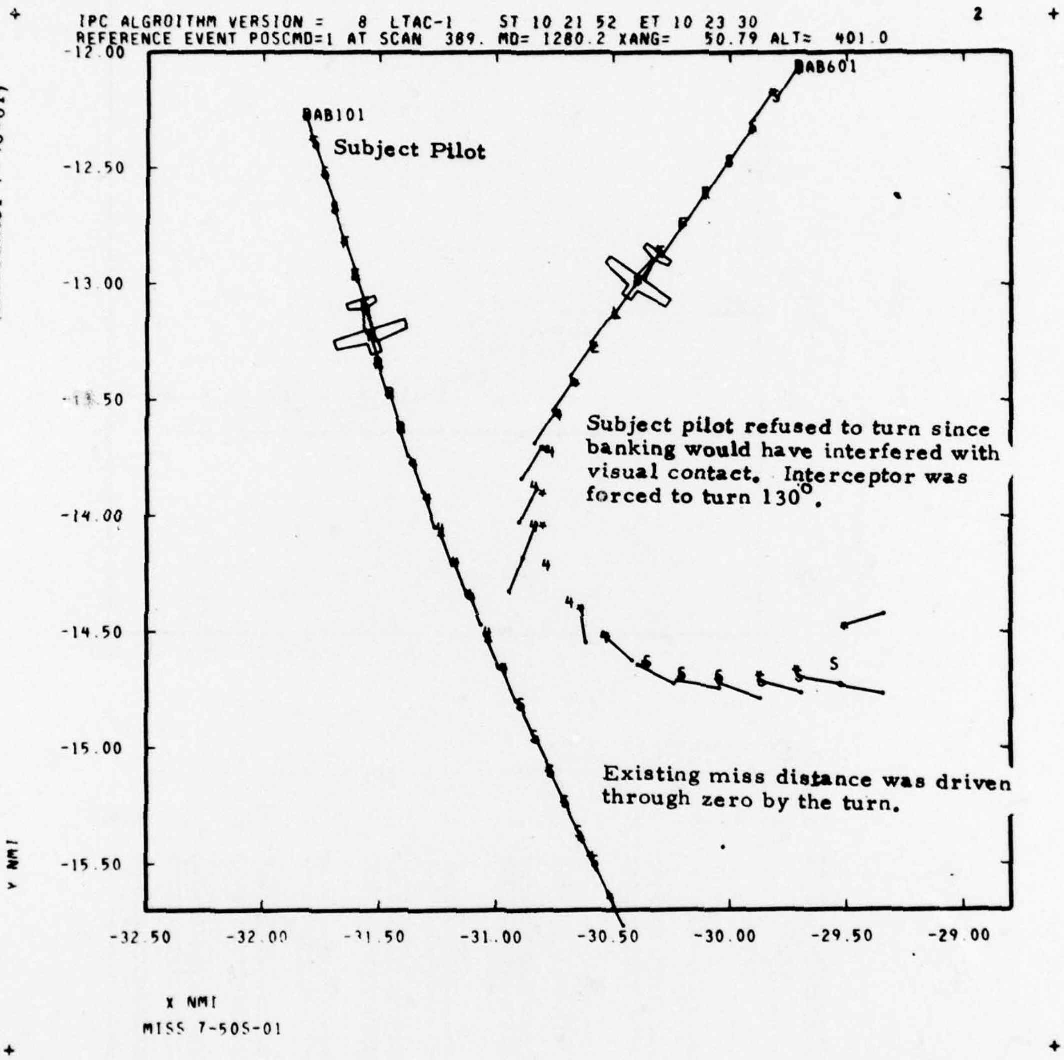
IPC ALGROITHM VERSION = 8 LTAC-1 ST 10 39 15 ET 10 40 19
REFERENCE EVENT NEG CMD AT SCAN 620. MD= 4064.5 XANG= 78.21 ALT= 295.5



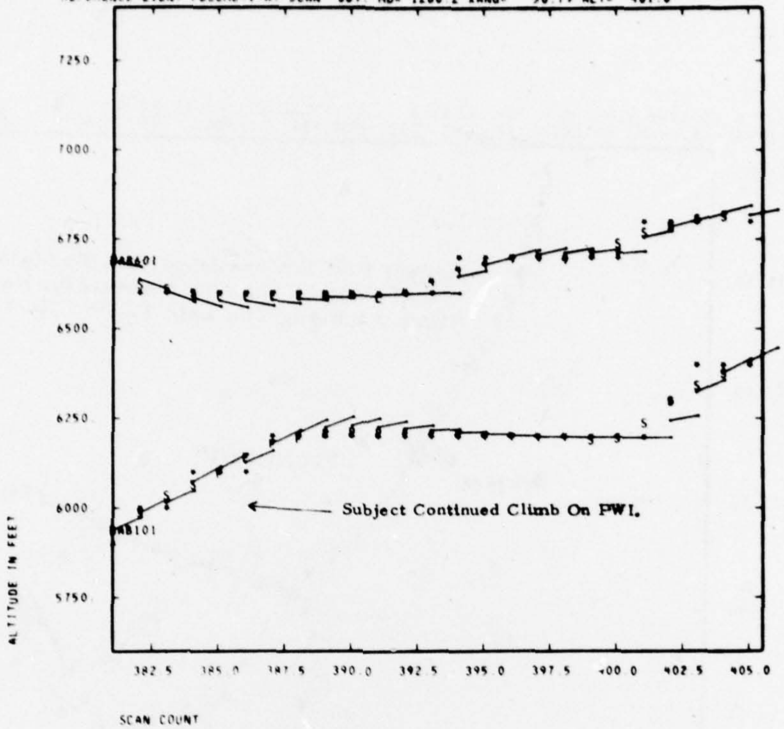
IPC ALGORITHM VERSION = 8 LTAC-1
CPAH = 4984.484 CPAV = 79.973
CPA ON SCAN 624 SCPA = 4985.887 SCPAH = 4984.484 SCPAV = 118.293
AC1 TRACK = 3 ID = DAB601 VFR
AC2 TRACK = 1 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
616			0	44.30	2.00	3137.	100.0	-300.01	0.0	300.01	-299.35	32.	0
617	F	F	0	39.49	1.82	3661.	100.0	-300.01	0.0	300.01	-274.11	32.	0
618	F	F	0	35.43	1.65	4356.	100.0	-300.01	0.0	300.01	-244.46	32.	0
619	F	F	-2	31.17	1.48	4273.	100.0	-300.01	0.0	299.98	-216.73	32.	2
620	F	F	0	28.06	1.33	4314.	100.0	-300.01	0.0	300.00	-186.58	32.	2
621	NL	NR	0	24.57	1.18	3963.	100.0	-300.01	0.0	299.99	-159.81	32.	2
622	NL	NR	0	22.64	1.06	4188.	71.5	-253.61	3.55	140.07	-128.14	32.	2
623	NL	NR	0	20.64	0.94	4279.	44.8	-221.01	4.94	62.99	-97.80	32.	2
624	NL	NR	0	20.40	0.84	4356.	18.1	-154.14	8.53	0.0	-68.96	32.	2
625	NL	NR	0	32.80	0.80	4678.	12.0	-110.59	9.24	0.0	-34.93	32.	0
626	F	F	0	90.67	0.76	4584.	10.3	-85.57	8.28	0.0	-9.67	32.	0
627	S	S	0	0.0	1.00	5610.	0.0	-74.11	0.0	74.11	68.56	32.	0
628	S	S	0	0.0	0.96	5080.	0.0	-71.87	0.0	71.87	77.13	32.	0
629	S	S	0	0.0	1.02	4962.	0.0	-74.67	0.0	74.67	97.53	32.	0
630	S	S	0	0.0	1.09	4909.	0.0	-79.82	0.0	79.82	114.31	32.	0
631	S	S	0	0.0	1.20	4956.	0.0	-85.54	0.0	85.54	133.31	32.	0
632	S	S	0	0.0	1.31	5003.	0.0	-137.08	0.0	137.08	152.10	32.	0

EXAMPLE 35
(Encounter 7-50-01)



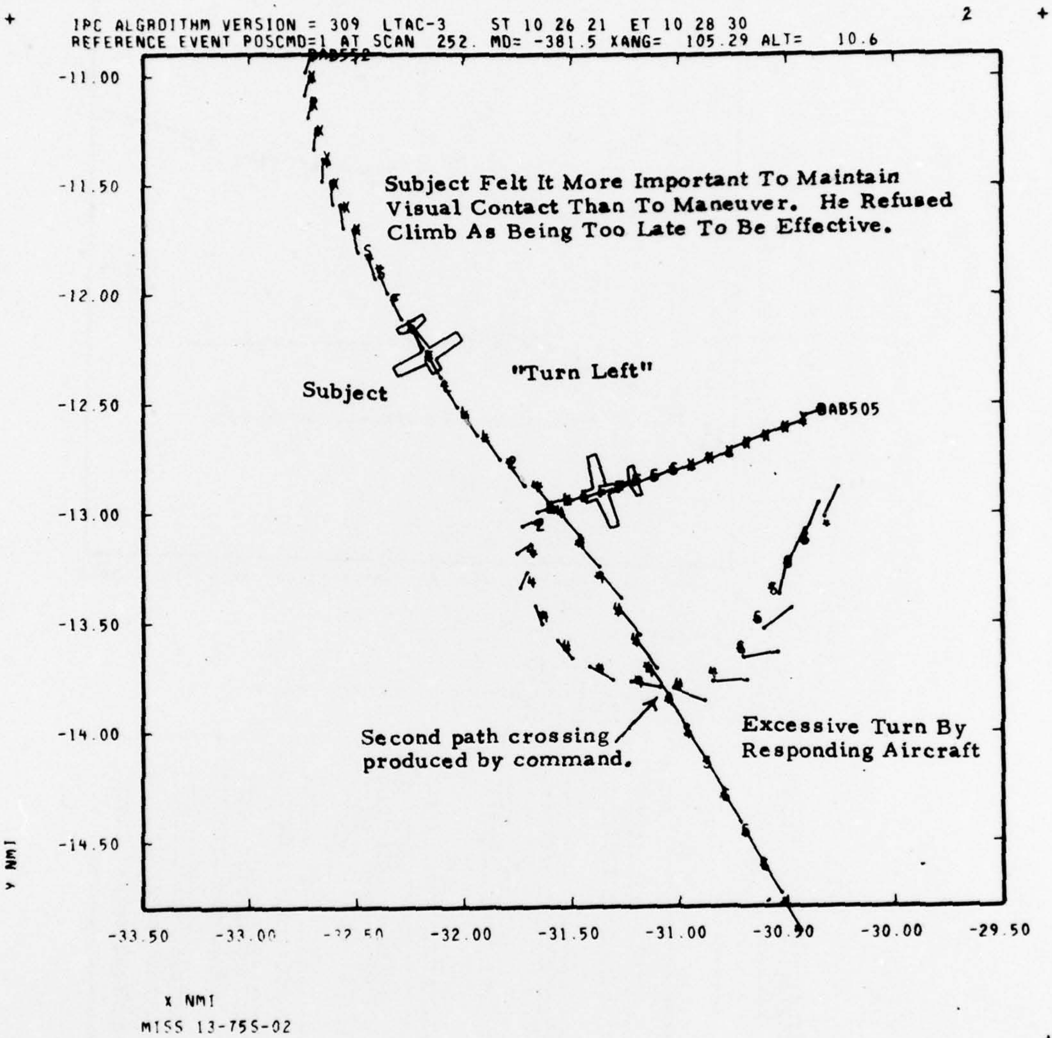
IPC ALGROITHM VERSION = 8 LTAC-1 ST 10 21 52 ET 10 23 30
REFERENCE EVENT POSCMD=1 AT SCAN 389 MD= 1280 2 XANG= 50 79 ALT= 401 0



IPC ALGORITHM VERSION = 8 LTAC-1
CPAH = 2118 989 CPAV = 377 074
CPA ON SCAN 396 SCPA = 2175 926 SCPAH = 2118 989 SCPAV = 494 512
AC1 TRACK = 1 ID = DAB601 VFR
AC2 TRACK = 2 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
381			0	60 91	2 25	2397	47 6	-775 13	16 27	254 42	-276 50	32	0
382	S	S	0	56 04	2 12	1991	57 6	-751 26	13 05	333 76	-262 95	32	0
383	S	S	0	51 45	1 98	1886	39 5	-652 68	16 53	123 67	-247 11	32	0
384	S	S	0	46 91	1 84	1506	37 0	-592 21	16 02	79 62	-230 32	32	0
385	S	S	0	42 32	1 70	1464	30 3	-514 53	16 98	0 0	-212 69	32	0
386	F	F	0	37 58	1 56	1283	31 3	-470 89	15 05	0 0	-195 13	32	0
387	F	F	0	32 77	1 42	1588	38 1	-451 58	11 85	72 23	-176 85	32	0
388	F	F	-2	28 46	1 28	1828	33 6	-401 85	11 98	18 58	-158 16	32	2
389	F	F	1	24 91	1 16	1624	36 3	-374 93	10 32	44 75	-140 08	32	2
390	L	R	1	20 41	1 03	1398	45 8	-364 11	7 94	109 93	-122 41	32	2
391	L	R	1	15 44	0 90	1307	65 8	-363 48	5 53	186 64	-105 25	32	2
392	L	R	4	9 45	0 78	1179	107 2	-368 40	3 44	258 46	-88 92	32	2
393	L	R	4	2 61	0 65	1243	206 1	-375 57	1 82	317 25	-72 66	32	2
394	L	R	4	-4 93	0 54	1251	553 9	-382 95	0 69	360 83	-57 74	32	2
395	L	R	4	-13 79	0 45	1062	-122 4	-435 75	-3 56	435 75	-45 61	32	2
396	L	R	4	-22 70	0 39	856	-88 9	-473 31	-5 33	473 31	-35 88	32	2
397	L	R	4	-44 19	0 28	789	-89 9	-497 89	-5 54	497 89	-24 57	32	2
398	L	R	4	-52 30	0 42	36	-104 5	-507 86	-4 86	507 86	-14 46	32	2
399	L	R	0	0 0	0 45	560	0 0	-513 21	0 0	513 21	26 54	32	0
400	S	S	0	0 0	0 54	943	0 0	-514 82	0 0	514 82	52 09	32	0
401	S	S	0	0 0	0 66	1524	0 0	-513 57	0 0	513 57	88 74	32	0
402	S	S	0	0 0	0 81	724	0 0	-557 35	0 0	557 35	97 20	32	0
403	S	S	0	0 0	0 98	721	0 0	-540 53	0 0	540 53	128 95	32	0
404	S	S	0	0 0	1 16	822	0 0	-479 28	0 0	479 28	163 73	32	0
405	S	S	0	0 0	1 30	773	0 0	-446 25	0 0	446 25	180 40	32	0

EXAMPLE 36
(Encounter 13-75-02)



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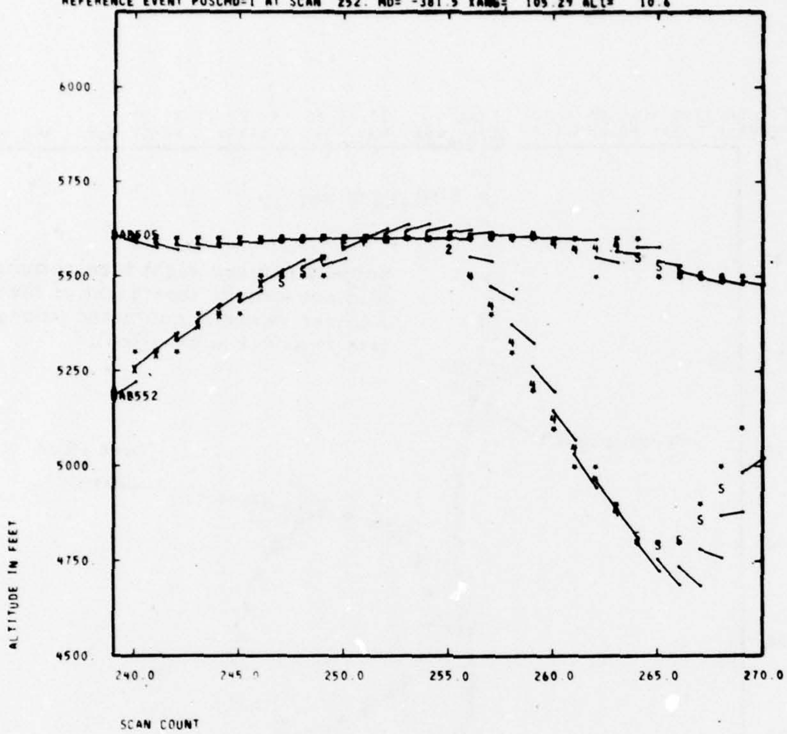
IPC ALGORITHM VERSION = 309 LTAC-3 ST 10 26 21 ET 10 28 30
REFERENCE EVENT POSCMD=1 AT SCAN 252. MD= -381.5 XANG= 105.29 ALT= 10.6



IPC ALGORITHM VERSION = 309 LTAC-3
CPAH = 852.731 CPAV = 2.371
CPA ON SCAN 262 SCPR = 1047.334 SCPAH = 852.731 SCPAV = 608.078
AC1 TRACK = 3 ID = DAB505 VFR
AC2 TRACK = 2 ID = DAB552 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
239	X	X	0	184.57	3.01	5582.	39.0	503.08	-12.91	90.06	-172.75	32.	0
240	X	X	0	151.26	2.88	4999.	29.3	425.50	-14.50	0.0	-192.67	32.	0
241	X	X	0	134.52	2.78	4181.	20.1	333.82	-16.61	0.0	-201.85	32.	0
242	X	X	0	118.63	2.67	3303.	18.2	279.75	-15.35	0.0	-209.82	32.	0
243	X	X	0	100.97	2.52	2828.	20.3	253.29	-12.47	0.0	-219.54	32.	0
244	X	X	0	84.01	2.36	2325.	16.0	199.72	-12.46	0.0	-229.51	32.	0
245	X	X	0	74.59	2.23	1504.	16.0	170.74	-10.66	0.0	-229.41	32.	0
246	X	X	0	63.98	2.06	852.	19.4	158.96	-8.17	0.0	-227.47	32.	0
247	X	X	0	55.77	1.91	85.	12.6	112.68	-8.96	0.0	-221.40	32.	0
248	S	S	0	46.17	1.72	146.	10.6	86.14	-8.09	0.0	-214.22	32.	0
249	S	S	0	41.78	1.59	917.	11.4	73.66	-6.47	0.0	-199.21	32.	0
250	F	F	0	34.67	1.41	864.	15.1	70.68	-4.67	0.0	-183.10	32.	0
251	F	F	-2	27.65	1.22	896.	4.3	27.04	-6.35	0.0	-165.19	32.	2
252	F	F	1	20.71	1.03	814.	-0.0	-0.25	-6.34	0.25	-144.82	32.	2
253	L	L	1	13.88	0.84	684.	-2.7	-14.74	-5.42	14.74	-122.04	32.	2
254	L	L	1	5.92	0.63	485.	-4.9	-20.38	-4.14	20.38	-95.65	32.	2
255	L	L	2	-1.65	0.46	660.	-7.1	-20.49	-2.86	20.49	-69.24	32.	2
256	L D	L C	4	-13.83	0.31	979.	-10.0	-17.59	-1.77	17.59	-40.43	32.	2
257	L D	L C	4	-45.04	0.27	1524.	-14.0	-59.89	-4.28	59.89	-14.66	32.	2
258	L D	L C	4	-59.86	0.31	1870.	-16.1	-134.77	-8.35	134.77	-10.00	32.	2
259	L D	L C	4	-53.58	0.36	2154.	-18.2	-230.64	-12.70	230.64	-10.00	32.	2
260	L D	L C	4	-60.18	0.37	2103.	-20.4	-338.35	-16.57	338.35	-10.00	32.	2
261	L D	L C	4	-54.91	0.30	478.	-23.0	-451.54	-19.59	451.54	-16.12	32.	2
262	L D	L C	4	-64.82	0.19	249.	-26.0	-565.48	-21.76	565.48	-18.11	32.	2
263	L D	L C	4	-129.63	0.14	865.	-35.6	-585.12	-16.43	585.12	-10.00	32.	2
264	L D	L C	0	53.07	0.21	813.	-37.8	-676.28	-17.91	676.28	23.42	32.	0
265	S	S	0	12.05	0.42	408.	-39.8	-774.96	-19.47	774.96	65.88	32.	0
266	S	S	0	-1.18	0.66	800.	-55.5	-785.16	-14.16	785.16	134.61	32.	0
267	S	S	0	-7.96	0.95	2279.	-84.0	-778.29	-9.26	778.29	231.27	32.	0
268	S	S	0	-13.22	1.25	1535.	-366.2	-716.93	-1.96	716.93	313.59	32.	0
269	S	S	0	-17.72	1.51	1607.	112.4	-620.83	5.52	444.13	382.29	32.	0

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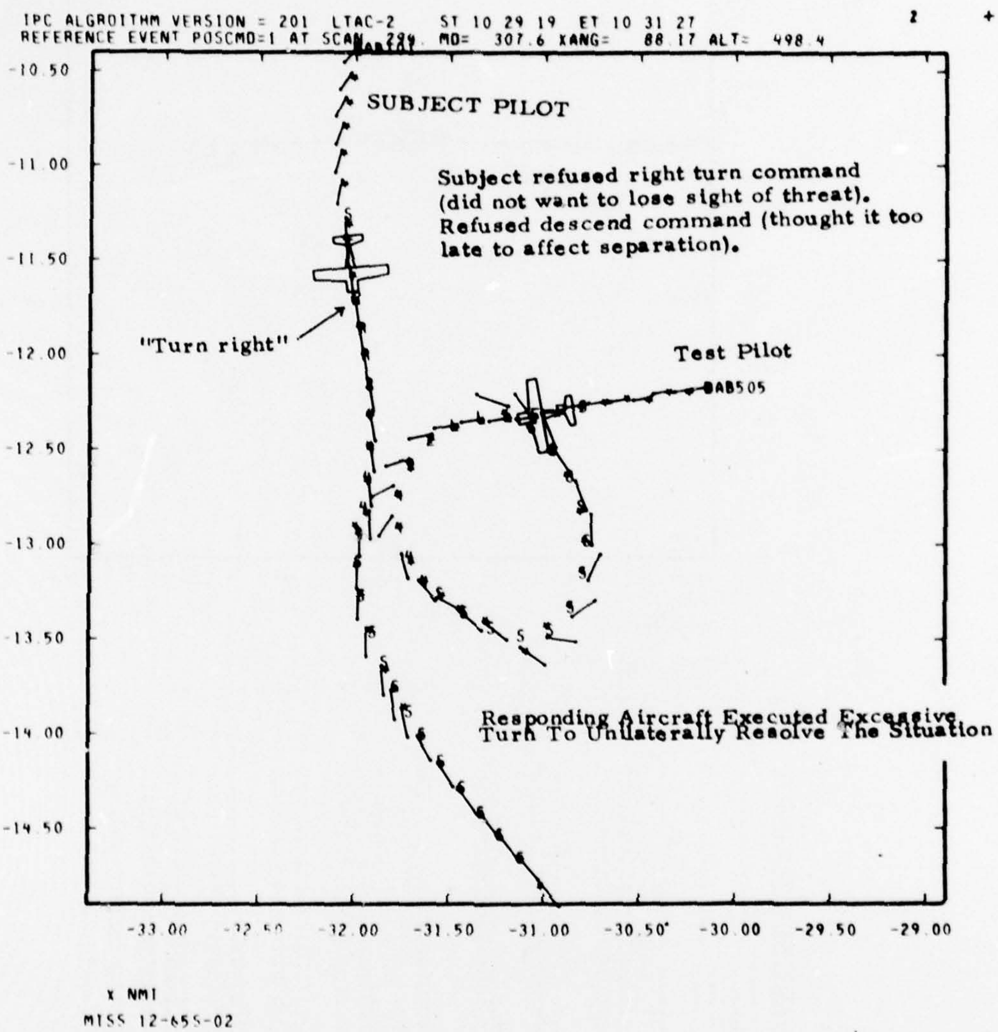
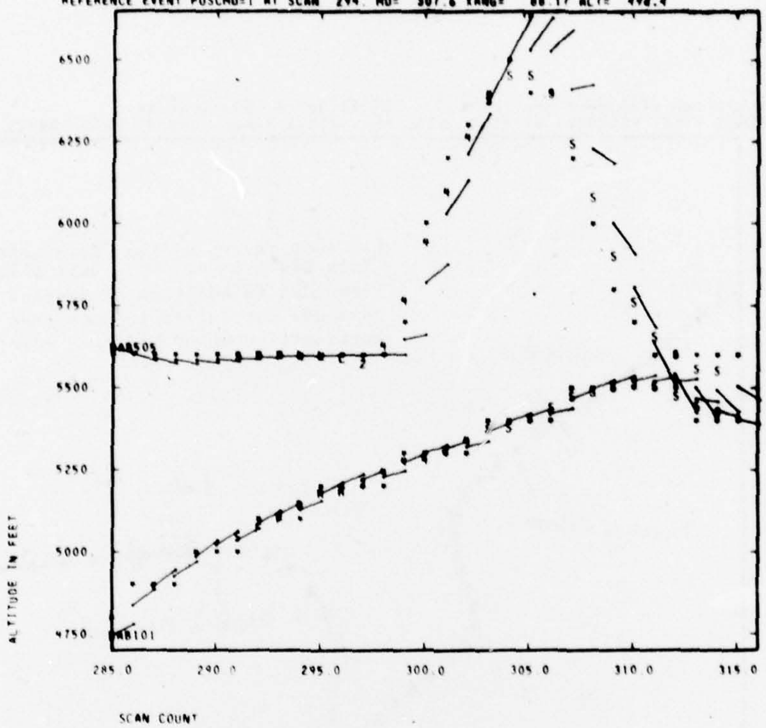
EXAMPLE 37
(Encounter 12-65-02)



IPC ALGROITHM VERSION = 201 LTAC-2   ST 10 29 19 ET 10 31 27
REFERENCE EVENT POSCMD=1 AT SCAN 294. MD= 307.6 XANG= 88.17 ALT= 498.4



IPC ALGORITHM VERSION = 201 LTAC-2
CPAH = 1778.708 CPAV = 113.262
CPA ON SCAN 299 SCPA = 1844.612 SCPAH = 1778.708 SCPAV = 488.660
AC1 TRACK = 1 ID = DAB505 VFR
AC2 TRACK = 3 ID = DAB101 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
291			0	52.87	1.82	3205.	45.9	-566.82	12.34	172.05	-207.16	32.	0
292	S	S	0	35.54	1.59	1857.	58.5	-553.37	9.47	250.49	-228.52	32.	0
293	F	F	-2	30.43	1.44	1340.	51.4	-506.28	9.85	191.12	-212.08	32.	2
294	F	F	1	23.16	1.23	1084.	55.6	-480.35	8.64	203.92	-189.08	32.	2
295	L	R	1	16.03	1.01	867.	69.5	-469.14	6.75	253.14	-161.80	32.	2
296	L	R	1	9.62	0.81	543.	51.8	-421.80	8.14	161.39	-133.57	32.	2
297	L	R	2	2.63	0.62	225.	51.0	-393.23	7.71	146.59	-103.15	32.	2
298	L C	R D	4	-6.68	0.43	8.	59.4	-378.53	6.37	174.61	-71.18	32.	2
299	L C	R D	4	-16.36	0.31	448.	78.7	-373.59	4.75	221.73	-48.19	32.	2
300	L C	R D	4	-28.81	0.25	734.	117.2	-374.75	3.20	272.43	-31.71	32.	2
301	L C	R D	4	-60.26	0.24	821.	-64.3	-518.23	-8.05	518.23	-15.67	32.	2
302	L C	R D	4	-90.85	0.29	1765.	-36.1	-713.77	-19.77	713.77	-10.00	32.	2
303	L C	R D	0	0.0	0.41	2174.	0.0	-890.98	0.0	890.98	16.96	32.	0
304	S	S	0	0.0	0.46	2202.	0.0	-1001.83	0.0	1001.83	38.99	32.	0
305	S	S	0	0.0	0.54	1703.	0.0	-1107.46	0.0	1107.46	52.70	32.	0
306	S	S	0	0.0	0.62	1479.	0.0	-1117.93	0.0	1117.93	66.91	32.	0
307	S	S	0	0.0	0.74	1536.	0.0	-1106.33	0.0	1106.33	83.60	32.	0
308	S	S	0	0.0	0.86	2307.	0.0	-945.36	0.0	945.36	128.39	32.	0
309	S	S	0	0.0	1.03	3929.	0.0	-730.87	0.0	730.87	179.83	32.	0
310	S	S	0	0.0	1.21	5555.	0.0	-489.48	0.0	489.48	190.95	32.	0
311	S	S	0	0.0	1.40	6623.	0.0	-286.18	0.0	286.18	236.50	32.	0
312	S	S	0	0.0	1.61	7623.	0.0	-117.46	0.0	117.46	286.08	32.	0
313	S	S	0	0.0	1.85	8560.	0.0	-23.95	0.0	23.95	352.90	32.	0
314	S	S	0	0.0	2.06	7560.	0.0	-34.06	0.0	34.06	484.84	32.	0
315	S	S	0	0.0	2.30	8870.	0.0	-63.50	0.0	63.50	528.94	32.	0

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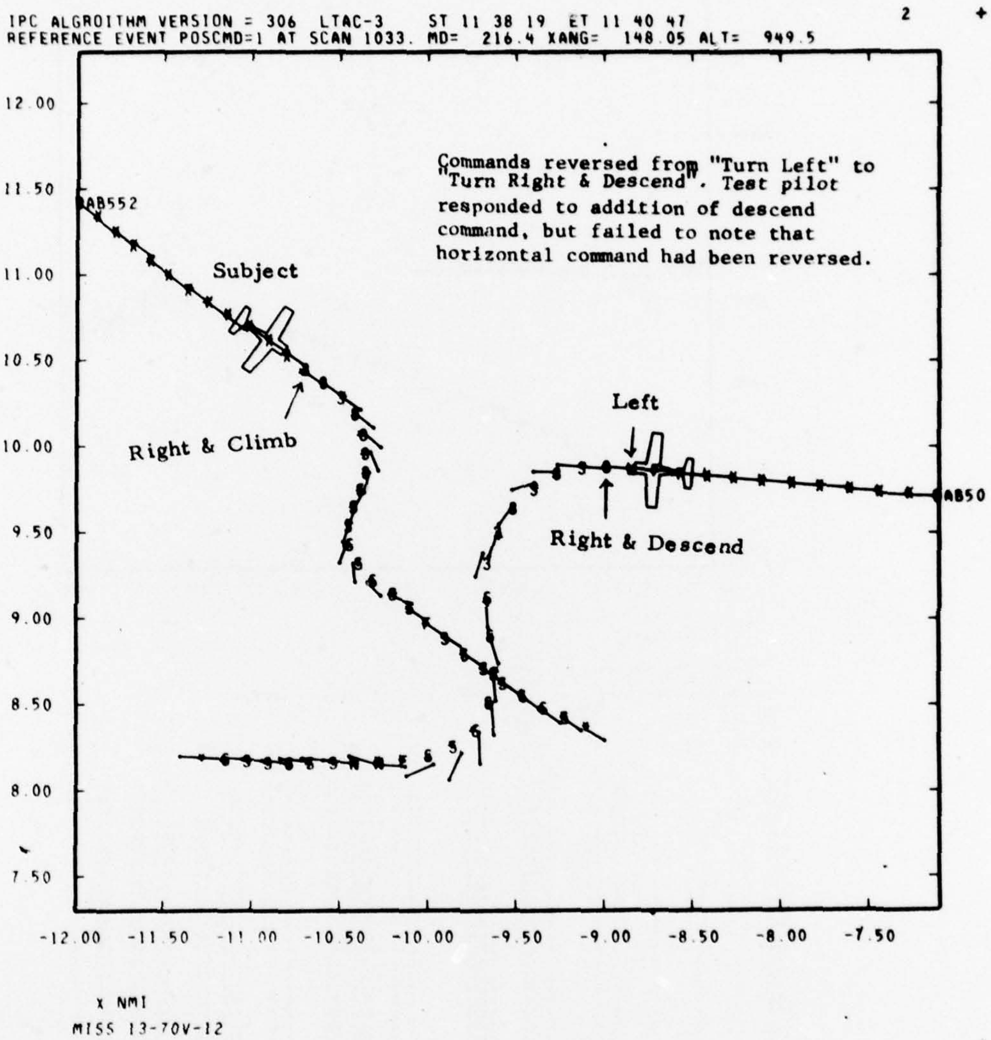
EXAMPLE 38
(Encounter 13-70-12)



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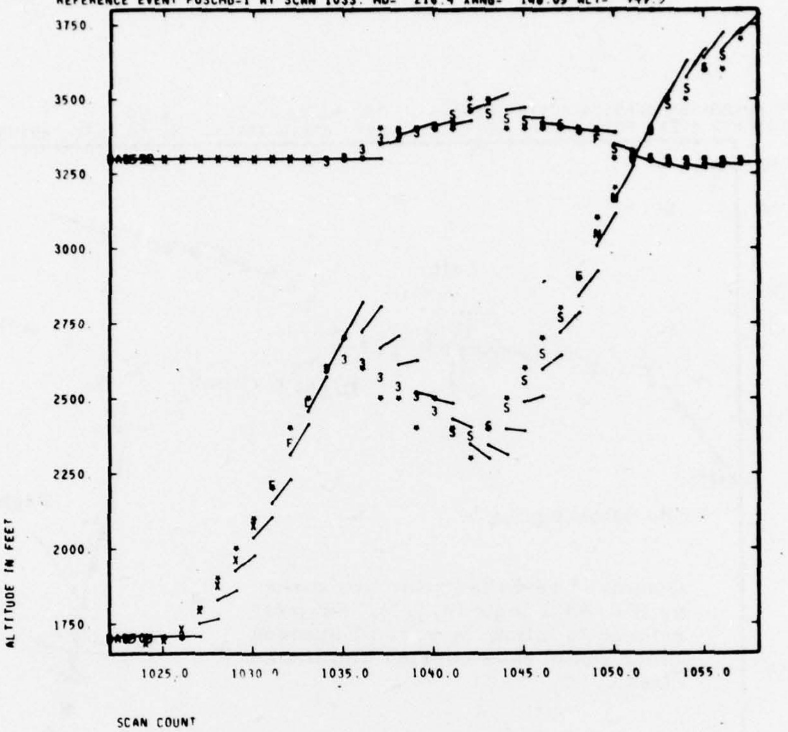
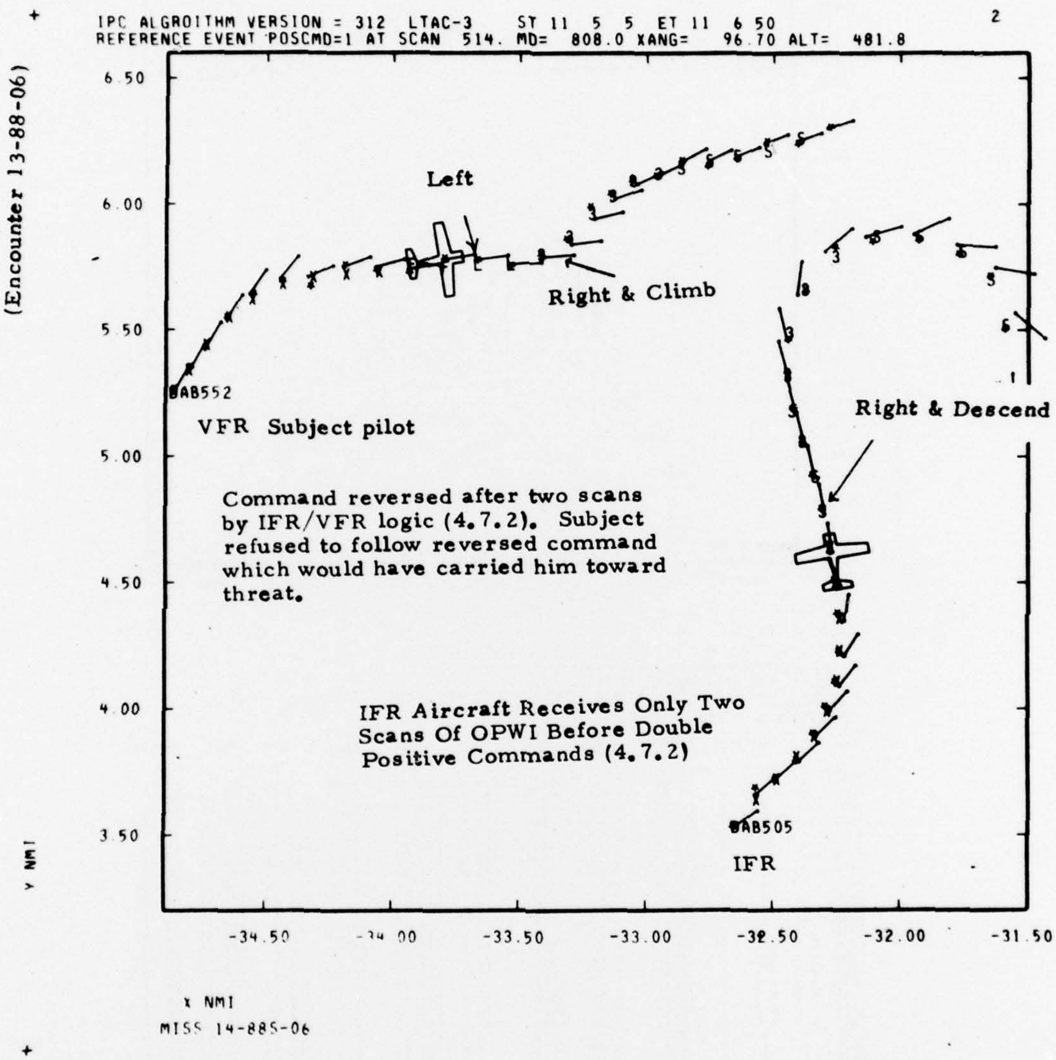
IPC ALGROITHM VERSION = 306 LTAC-3 ST 11 38 19 ET 11 40 47
REFERENCE EVENT POSCMD=1 AT SCAN 1033. MD= 216.4 XANG= 148.05 ALT= 949.5



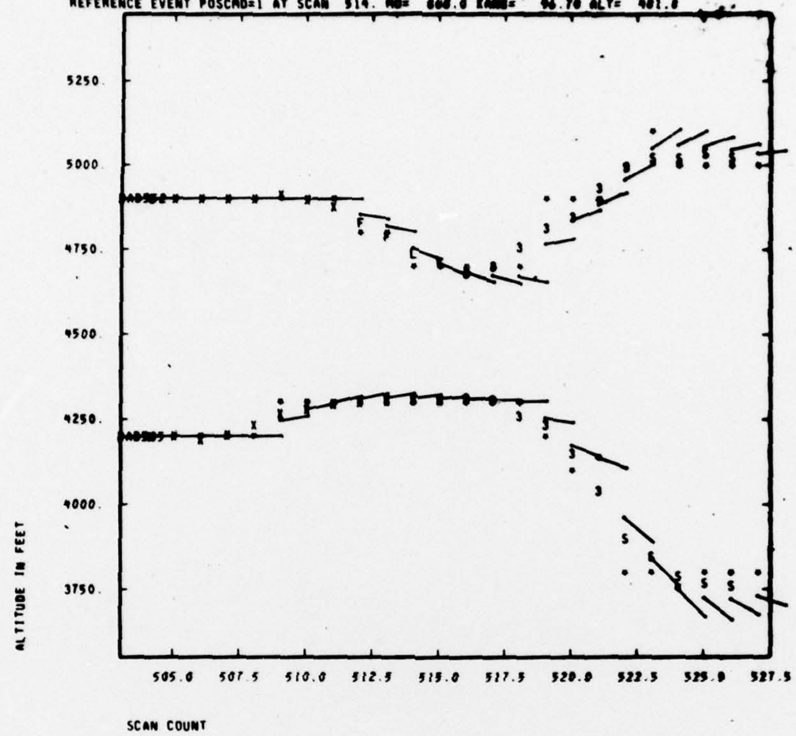
IPC ALGORITHM VERSION = 306 LTAC-3
CPAH = 5181.687 CPAV = 18.347
CPA ON SCAN 1049 SCPA = 5191.434 SCPAH = 5181.687 SCPAV = 317.976
AC1 TRACK = 1 ID = DAB505 VFR
AC2 TRACK = 2 ID = DAB552 IFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
1022	X	X	0	76.82	5.47	316.	834.9	1604.89	-1.92	1474.18	-1383.61	68.	0
1023	X	X	0	72.72	5.17	469.	882.0	1598.27	-1.81	1475.05	-1305.20	68.	0
1024	X	X	0	68.97	4.88	108.	1069.0	1594.98	-1.49	1493.52	-1225.65	68.	0
1025	X	X	0	65.02	4.59	53.	1441.4	1593.93	-1.11	1518.73	-1148.01	68.	0
1026	X	X	0	61.08	4.30	95.	2158.0	1594.25	-0.74	1544.02	-1071.40	68.	0
1027	X	X	0	57.15	4.02	328.	3655.7	1595.25	-0.44	1565.57	-995.29	68.	0
1028	X	X	0	53.26	3.74	483.	426.6	1550.07	-3.63	1302.98	-920.05	68.	0
1029	X	X	0	48.81	3.44	353.	178.9	1472.21	-8.23	912.70	-848.03	68.	0
1030	X	X	0	44.73	3.16	324.	106.3	1373.70	-12.92	495.04	-775.53	68.	0
1031	X	X	0	40.52	2.87	254.	74.4	1263.94	-17.00	107.89	-703.61	68.	0
1032	F	X	-2	36.42	2.59	22.	57.1	1149.43	-20.15	0.0	-632.12	68.	2
1033	F	X	1	32.37	2.32	125.	38.4	988.13	-25.76	0.0	-561.09	68.	2
1034	L	X	3	28.74	2.06	4.	29.6	842.53	-28.47	0.0	-490.93	68.	2
1035	R D	R C	3	25.10	1.81	272.	24.4	712.15	-29.24	0.0	-422.48	68.	2
1036	R D	R C	3	21.16	1.55	310.	20.6	593.99	-28.86	0.0	-356.50	68.	2
1037	R D	R C	3	16.84	1.30	262.	27.4	578.04	-21.08	0.0	-293.43	68.	2
1038	R D	R C	3	14.61	1.09	1512.	96.7	679.90	-7.03	201.72	-216.41	68.	2
1039	R D	R C	3	17.63	0.93	3368.	-515.4	766.11	1.49	766.11	-116.78	68.	2
1040	R D	R C	3	33.80	0.86	3987.	-94.6	878.02	9.28	878.02	-46.44	68.	2
1041	R D	R C	0	119.86	0.80	4825.	-105.5	908.13	8.60	908.13	-10.00	68.	0
1042	S	S	0	0.0	0.95	470.	0.0	981.53	0.0	981.53	70.43	68.	0
1043	S	S	0	0.0	1.07	1373.	0.0	1112.54	0.0	1112.54	91.01	68.	0
1044	S	S	0	0.0	1.18	1141.	0.0	1146.47	0.0	1146.47	93.12	68.	0
1045	S	S	0	0.0	1.24	1239.	0.0	1065.08	0.0	1065.08	103.60	68.	0
1046	S	S	0	0.0	1.22	4870.	0.0	951.30	0.0	951.30	64.78	68.	0
1047	S	S	0	327.07	1.12	6831.	61.6	822.17	-13.35	0.0	-10.00	68.	0
1048	S	S	-2	59.25	1.02	6094.	36.2	688.94	-19.02	0.0	-41.89	68.	2
1049	F	S	0	29.34	0.92	5410.	24.6	558.15	-22.72	0.0	-61.60	68.	2
1050	NR	F	0	54.26	0.87	5251.	13.7	387.21	-28.30	0.0	-26.41	68.	2
1051	NR	S	0	0.0	0.90	5213.	0.0	189.90	0.0	189.90	69.99	68.	0
1052	S	S	0	0.0	0.98	5139.	0.0	25.04	0.0	25.04	126.82	68.	0
1053	S	S	0	0.0	1.14	5207.	0.0	-113.62	0.0	113.62	185.83	68.	0
1054	S	S	0	0.0	1.31	5244.	0.0	-232.28	0.0	232.28	235.28	68.	0
1055	S	S	0	0.0	1.50	5279.	0.0	-291.24	0.0	291.24	285.22	68.	0
1056	S	S	0	0.0	1.70	5295.	0.0	-356.25	0.0	356.25	329.44	68.	0
1057	S	S	0	0.0	1.94	5328.	0.0	-382.79	0.0	382.79	381.12	68.	0

EXAMPLE 39
(Encounter 13-88-06)



IPC ALGROITHM VERSION = 312 LTAC-3 ST 11 5 5 ET 11 6 50
REFERENCE EVENT POSCMD=1 AT SCAN 514. MD= 600.0 RANG= 96.70 ALT= 401.0



IPC ALGORITHM VERSION = 312 LTAC-3
CPAH = 4717.621 CPAV = 366.184
CPA ON SCAN 521 SCPA = 4800.910 SCPAH = 4717.621 SCPAV = 890.378
AC1 TRACK = 4 ID = DAB505 IFR
AC2 TRACK = 1 ID = DAB552 VFR

SCAN	AC1	AC2	POS	TH	RANGE	MD	TV	RZ	VZ	VMD	DOT	TCMD	NAC
503	X	X	0	-236.42	2.75	1441.	100.0	-700.07	0.01	699.64	111.64	68	0
504	X	X	0	-245.34	2.81	3219.	90982.6	-700.02	0.01	699.50	111.83	68	0
505	X	X	0	-292.22	2.80	2309.	95759.7	-700.00	0.01	699.50	93.77	68	0
506	X	X	0	-332.27	2.83	2192.	100.0	-699.98	0.01	699.57	84.15	68	0
507	X	X	0	-374.78	2.86	3695.	100.0	-699.98	0.0	699.66	75.92	68	0
508	X	X	0	-515.62	2.84	6173.	100.0	-699.98	0.0	699.75	54.44	68	0
509	X	X	0	-1818.06	2.76	13670.	100.0	-699.98	0.0	699.83	14.64	68	0
510	X	X	0	198.99	2.65	2792.	198.7	-653.59	3.29	429.92	-122.64	68	0
511	X	X	0	137.85	2.51	1491.	135.7	-621.00	4.58	309.75	-158.46	68	0
512	X	X	0	72.15	2.32	36.	130.3	-600.51	4.61	287.14	-255.93	68	0
513	X	F	-2	45.77	2.11	1927.	74.9	-543.03	7.25	50.10	-328.85	68	2
514	X	F	1	42.96	1.92	516.	66.4	-506.03	7.62	0.0	-286.65	68	2
515	S	L	1	34.48	1.69	57.	43.8	-438.98	10.01	0.0	-270.75	68	2
516	S	L	3	27.15	1.46	352.	40.3	-397.36	9.86	0.0	-246.79	68	2
517	R D	R C	3	21.83	1.27	303.	45.0	-375.46	8.35	0.0	-217.56	68	2
518	R D	R C	3	17.92	1.10	92.	57.9	-367.24	6.34	0.0	-185.91	68	2
520	R D	R C	3	13.66	0.87	521.	-71.1	-511.60	-7.20	511.60	-126.64	68	2
521	R D	R C	3	14.35	0.77	1057.	-42.4	-662.34	-15.63	662.34	-81.24	68	2
522	R D	R C	0	87.23	0.73	4370.	-44.9	-744.34	-16.59	744.34	-10.00	68	0
523	S	S	0	-32.36	0.78	1034.	-34.1	-994.71	-29.18	994.71	35.33	68	0
524	S	S	0	-50.75	0.86	3503.	-34.4	-1204.86	-35.01	1204.86	31.35	68	0
525	S	S	0	-32.07	0.94	1396.	-41.7	-1306.25	-31.33	1306.25	65.82	68	0
526	S	S	0	-33.67	1.03	1769.	-57.0	-1330.39	-23.32	1330.39	80.05	68	0
527	S	S	0	-32.82	1.10	4447.	-84.5	-1324.65	-15.68	1324.65	99.68	68	0